ENGINEERING ENCYCLOPEDIA

A Condensed Encyclopedia and Mechanical Dictionary for Engineers, Mechanics, Technical Schools, Industrial Plants, and Public Libraries, Giving the Most Essential Facts about 4500 Important Engineering Subjects

Edited by

FRANKLIN D. JONES

and

PAUL B. SCHUBERT

THE INDUSTRIAL PRESS
93 WORTH STREET, NEW YORK 13, N. Y.
MACHINERY PUBLISHING CO., LTD.
National House, West Street,
Brighton 1, England

ENGINEERING ENCYCLOPEDIA

Library of Congress Catalog Card Number: 63-10415

ENGINEERING ENCYCLOPEDIA

A

Abrasive. An abrasive, such as is used in making grinding wheels or abrasive cloth and paper, may either be natural or artificial. The natural abrasives, such as emery and corundum, have been replaced largely by artificial abrasives, of which there are two general classes. One class is known as silicon carbide abrasives and the other as aluminous abrasives. The raw materials used in making the silicon carbide abrasives are pure glass or silica sand and carbon supplied by coke of various grades. The aluminous abrasives are made from bauxite, which is mined in the southern part of the United States and in various other parts of the world. The two general classes of abrasives mentioned are sold under various trade names. For information about the applications of the silicon carbide and aluminous abrasives see Grinding Wheel Selection. See also Aluminum Oxide and Silicon Carbide.

Abrasive Belt Grinding. This production grinding process is performed on machines making use of belts of strong cloth onto which have been coated abrasives similar to those used in grinding wheels. This coated cloth resembles the familiar "emery cloth."

Machines may be dry-belt, wet-belt, or a combination type. In wet-belt grinding, liquid coolants are applied to the grinding area to dissipate heat and to prevent overloading and clogging of the abrasive belt. This method permits high-speed grinding of ferrous and non-ferrous metals, glass, plastics, and other materials.

On machines, the belts are slipped over two drums (uncoated side in contact with drum surface), one of which is driven at high speed. A heavy plate or platen located between the two drums permits the workpiece to be pushed against the moving belt by providing support. The plate may also be shaped to suit the shape of a particular workpiece. Most machines are vertical, that is, the belt runs up and down, but some models are made with the belt in a horizontal position.

In another design, one of the drums acts as the backing plate and may be made of a flexible material so it will yield when a

curved workpiece is pressed against it and permit the belt to follow the contour of the work.

Abrasive-belt machines may be used for light polishing work or for heavy stock removal, and are true grinding machines.

Abrasive Grading. The modern method of grading abrasives is by the use of screens or sieves having openings between wires of certain standard dimensions. These screens conform to a table in which the wire diameters and the tolerances for both wire diameters and openings are given. Formerly, the number of screen meshes per lineal inch was used to indicate the screen size, but it is evident that accurate screening must take into account possible variations in wire sizes.

The screens used in testing commercial abrasives are made according to specifications of the Bureau of Standards. The openings in successive screen sizes vary by the fourth root of 2, so that every screen is 1.189 times the size of the preceding one. The standard screen or sieve number differs slightly in most cases from the actual number of meshes per inch. For example, a No. 10 screen has 9.2 meshes per inch. A No. 100 screen has 101 meshes per inch, there being slight variations throughout the series with a few exceptions.

The standard screen numbers are applied to loose abrasives used in polishing and also to abrasives used in grinding wheel manufacture. The arbitrary numbers or symbols, such as varying numbers of ciphers, for indicating the grading of certain classes of abrasive paper and cloth have been largely superseded by the standard screen numbers. This standard system of grading abrasives has been adopted by the Grinding Wheel Manufacturers' Association of United States and Canada.

Abrasive Grit Number. Standard abrasive grain sizes are designated by numbers. These numbers range from number 8, which is the coarsest, to number 240, which is the finest. The allowable limits for the sizing of aluminum-oxide and silicon-carbide abrasives for grinding-wheel manfacture are given in U. S. Simplified Practice Recommendation 118. These numbers in most cases equal approximately the number of sieve openings per inch in the United States Standard Fine Sieve series. For example, a number 30 sieve has 0.0232-inch openings and a sieve wire diameter of 0.0130 inch, making the pitch equal to 0.0362 inch; hence there are 27.6 meshes per inch. The United States Standard Fine Sieve series ranges from number 3½ to number 400.

Grading Abrasives: **In the actual grading of abrasives, several standard sieves are used. To illustrate, take grit No. 10.**

All material must pass through the coarsest sieve—in this case the No. 7. Through the next to the coarsest sieve, termed the "control sieve"—in this case the No. 8—all material may pass, but not more than 15 per cent may be retained on it. At least 45 per cent must pass through No. 8, and be retained on No. 10 sieve, but it is permissible to have 100 per cent pass through No. 8, and remain on No. 10 sieve, the requirement being that the grain passing through No. 8, and retained on No. 10 and No. 12 must add to at least 80 per cent; consequently, if 45 per cent passed through No. 8 sieve and was retained on No. 10 sieve, then at least 35 per cent must be retained on the No. 12 sieve. Not more than 3 per cent is permitted to pass through the No. 14 sieve.

Abrasive-Wheel Cutting Off Process. See Cutting Off Stock with Abrasive Wheels.

Abscissa. In analytical geometry, points are located by designating their distance from two given intersecting lines or axes. In Fig. 1, *XX* and *YY* are the axes, generally known as *coordinate* axes. These intersect at point *O*, called the *origin*. The distances measured parallel to axis *XX* are known as *abscissas;* those mea-

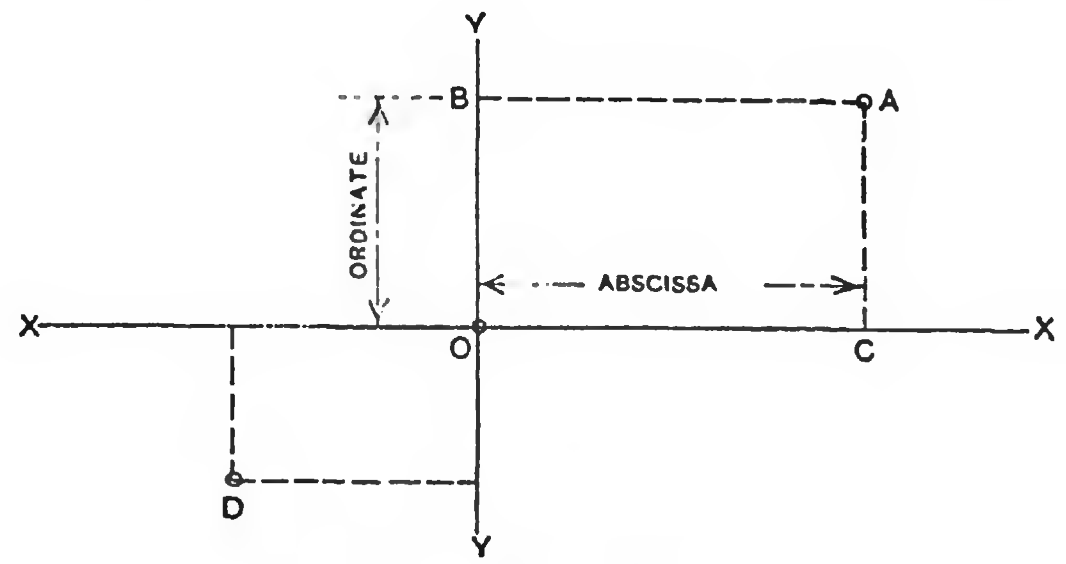


Fig. 1. Rectangular Coordinates

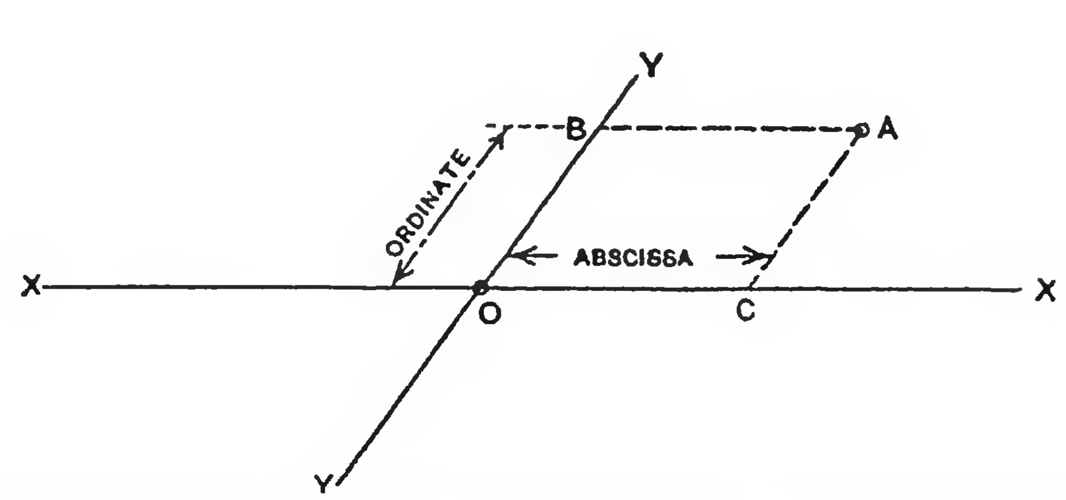


Fig. 2. Measurement of Abscissas and Ordinates

sured parallel to axis *YY*, *ordinates*. In mathematical expressions, the abscissa of a point is generally designated by the letter x and the ordinate by y. The two axes are generally at right angles to each other, in which case they are called *rectangular coordinates*. If the axes are not at right angles to each other, the abscissas and ordinates are measured along lines *parallel* to the axes, and not along lines at right angles to the axes. This is indicated in Fig. 2. The location of the axes is assumed to be known; the location of any point in the same plane, as *A*, can then be given in terms of its distance from the two axes. For example, if *AC* equals 2 inches, and *AB*, 3 inches, the location of point *A* is definitely given with relation to the axes and the origin.

Abscissas measured to the right of axis *YY* are *positive* in value, those measured to the left are *negative*. Ordinates measured above the axis *XX* are positive, those measured below, negative. Hence, both the abscissa and ordinate of point *A*, Fig. 1, are positive, but of point *D*, both are negative.

Absolute and Gage Pressure. The pressure of air, gases, or fluids is generally measured either in absolute pressure or in gage pressure. When measured in absolute pressure, the pressure of the atmosphere is included; the gage pressure is the pressure above that of the atmosphere. The pressure of air at sea level is 14.7 pounds per square inch. Gage pressure may be determined by simply subtracting 14.7 from the absolute pressure.

The steam pressure gage of a boiler measures gage pressure. All pressures used in compressed air computations should be measured from an absolute vacuum, which, for ordinary conditions, is 14.7 pounds per square inch below that of atmospheric or *gage* pressure. In like manner, the *absolute temperature* should be used, which for work of this kind may be assumed as equal to the degrees Fahrenheit plus 460.

Absolute Constant. See Constants in Mathematics.

Absolute Efficiency. See Efficiency of Mechanism.

Absolute System of Measurement. The system of measurement almost universally used in scientific work is based upon the length and weight units of the metric system, with the second as the time unit. The system is known as the C.G.S. (centimeter-gram-second) system or the "absolute system of measurement." As indicated by the letters C.G.S., the centimeter is the unit of length; the gram, the unit of mass (or weight); and the second, the unit of time. From these basic units are derived a number

of other units for measuring velocity, force, work, power, etc. These are:

Unit of velocity = 1 centimeter in one second.

Acceleration due to gravity (at Paris) = 981 centimeters in one second.

Unit of force = 1 dyne = 1/981 gram.

Unit of work = 1 erg = 1 dyne-centimeter.

Unit of power = 1 watt = 10,000,000 ergs per second.

The C.G.S. system of power measurements is used exclusively for electrical machines and apparatus on account of the simple relationship which exists between the various units. The unit of work, erg, is so small that in practical work the *joule* is usually employed instead. One joule equals 10,000,000 ergs.

Absolute Temperature and Absolute Zero. A point has been determined on the Fahrenheit and Centigrade thermometer scales, by theoretical considerations, which is called the absolute zero and beyond which a further decrease in temperature is inconceivable. It is the temperature at which a gas would show no pressure if the general law for gases would hold for all temperatures. This point is located at −273.2 degrees Centigrade or −459.7 degrees F. A temperature reckoned from this point, instead of from the zero on the ordinary thermometers, is called absolute temperature. Absolute temperature in degrees C. is known as "degrees Kelvin" or the "Kelvin scale" (K) and absolute temperature in degrees F. is known as "degrees Rankine" or the "Rankine scale" (R).

Degrees Kelvin = degrees C. + 273.2

Degrees Rankine = degrees F. + 459.7

Absolute Velocity. The absolute velocity of a moving body, is its velocity with reference to some object which is considered completely at rest. In practical mechanics, the earth is assumed to be stationary, so that the velocity of any moving body, as for example, a moving train with relation to the rails, would be absolute velocity. The term "absolute velocity" is used to distinguish it from *relative velocity,* which is the rate of motion of a body with relation to another moving body. See also Velocity.

Absorptiometer. The absorptiometer is an instrument invented by Prof. Bunsen, with which it is possible to determine the amount of gas absorbed by a unit volume of a liquid. In its simplest form, this instrument consists of a graduated tube in which a certain quantity of the gas and liquid is agitated over mercury. The amount of gas absorbed by the liquid is measured by the graduations on the scale; the height to which the mercury will rise in pressing up the liquid in the tube, when the gas has been partly absorbed, indicates the degree of absorption.

Absorption Dynamometers. See Dynamometers.

Absorption of Gases. Many liquids have a capacity for taking up or absorbing a certain quantity of gases. The quantity thus absorbed varies with the nature of the liquid and the gas. Many gases, for example, are readily absorbed by water; thus, water will absorb its own volume of carbonic-acid gas, over two times its volume of chlorine, and 430 times its volume of ammonia, but not more than 5 per cent of its volume of oxygen. The weight of gas that a given volume of liquid will absorb is proportionate to the pressure, but as the volume of a given mass of gas is proportionately less as the pressure increases, the volume which a given amount of liquid will absorb at a certain temperature is constant, whatever the pressure. Water, as mentioned, absorbs its own volume of carbonic-acid gas at atmospheric pressure. If the pressure is doubled on both the gas and water, it will still absorb its own volume of the gas under the higher pressure, but, in that case, the density of the gas is doubled and, consequently, double the weight of the gas is dissolved. The quantity of gas absorbed increases as the temperature is lowered. One of the most important instances of the absorption of gases by liquids is met with in the absorption of acetylene by acetone; the latter liquid absorbs, at 60 degrees F. and 180 pounds pressure per square inch, 300 volumes of acetylene gas. This property of acetone makes it possible to safely store and transport acetylene gas in steel cylinders or containers.

Acceleration. The rate of change in the velocity of a moving body is called *acceleration;* hence, the acceleration is the increase in velocity of a body during a very short interval of time, usually one second. When the motion is decreasing instead of increasing, it is called *retarded motion,* and the rate at which the motion is retarded is frequently called the *de-acceleration* or the *deceleration.* The acceleration is said to be uniform if the body gains equal increments of velocity in a given direction in equal successive units of time. A constant force produces a uniform acceleration. Gravity, for example, acting upon a falling body, causes it to fall with a uniformly accelerated motion, providing the effect of the atmospheric resistance is not considered. The acceleration due to gravity varies from 32.09 at the equator to 32.255 at the poles. The value at sea level and for a latitude of about 41 degrees is 32.16, which is the value commonly used.

Accumulator. See Hydraulic Accumulator.

Acetone. Acetone is a liquid obtained by the destructive distillation of acetates and produced, on a large scale, from the watery liquid obtained in the dry distillation of wood. It has the property of absorbing many times its volume of acetylene gas and is, therefore, used to a great extent in the oxy-acetylene welding and metal-cutting industry. The successful use of acetylene gas depends, to a great degree, upon the fact that it can be absorbed by acetone, and thus used without exposing those in the vicinity of the acetylene container to the dangers of a possible explosion from the gas. The method was invented by French engineers in 1896. One volume of acetone at 60 degrees F., under atmospheric pressure, will absorb 25 volumes of acetylene gas. At a pressure of 180 pounds per square inch, 300 volumes of the gas will be absorbed. Hence, by this method, an enormous quantity of acetylene gas can be stored and transported safely under comparatively low pressure, in cylinders of moderate size. When the pressure is relieved, the acetylene gas escapes gradually. The acetone can be used over and over again for the storage of acetylene gas, the loss in acetone being only about one pound for each 1000 cubic feet of acetylene. The porous substance used in the cylinders is a fine fibre or asbestos bound together with silicate of soda, melted in cakes to fill the interior of the cylinders for which they are intended. The material is porous and admits the acetone into the minute cavities.

Acetylene. Acetylene is a gaseous compound of carbon and hydrogen (chemical formula C_2H_2). It is a colorless gas having a specific gravity of 0.92 (air = 1). It is produced by the action of water upon calcium carbide. Acetylene gas cannot be stored in a compressed state directly in cylinders, because of the danger from explosion, but acetylene is soluble in a number of liquids, and, by dissolving in these liquids, acetylene may be stored with safety. Acetone is the liquid generally used for this purpose. Acetylene gas is of the greatest industrial importance in connection with autogenous welding and cutting of metals, where the great heat of combustion, when using it in conjunction with oxygen, is made use of. The oxygen-acetylene flame is far hotter than the oxy-hydrogen flame, and the fact that it is reducing in character is of great advantage in autogenous welding.

Acetylene was discovered in 1836, but until 1892 its production was merely a laboratory experiment. In that year calcium carbide was accidentally manufactured in an electric furnace at the works of the Willson Aluminum Co., in North Carolina. It was considered of no value and was thrown into the river. It was then accidentally discovered that the gas arising from it when thrown into water, would ignite, and a further investigation

proved that this was acetylene. Its commercial exploitation began shortly afterward in its use for isolated lighting plants.

Acheson Process. The method of making silicon carbide—an abrasive used for grinding wheels—by the electric process has, after the inventor, Dr. Acheson, been named the "Acheson process." Silicon-carbide abrasives are produced from quartz and carbon, these substances being heated in an electric resistance furnace. The furnace charge consists of quartz, carbon, sawdust, and sodium chloride. The abrasive is formed at a temperature of 1840 degrees C. (about 3340 degrees F.), and decomposes if it is heated above 2240 degrees C. (about 4060 degrees F.).

Acid. In chemistry, an acid is a compound containing hydrogen in which the hydrogen may be replaced by a metal, or a group of elements equivalent to a metal, to form a salt. An acid is also defined as a compound that will unite with a base to form a salt and water. Most acids are soluble in water, have a sour taste, turn vegetable blue into red, decompose most carbonates displacing the carbonic acid (carbon dioxide) with effervescence; they have also the power of destroying more or less completely the characteristic properties of alkalies. The acids in common use in the industries are hydrochloric, nitric, sulphuric, and hydrofluoric.

Acid Bessemer Process. See Bessemer Process.

Acid Firebrick. A firebrick in which silica predominates and which is generally known as "silica brick."

Acid, Hydrochloric. See Hydrochloric Acid.

Acid, Hydrofluoric. See Hydrofluoric Acid.

Acid Number of Oil. Free fatty acids represent the amount of free organic acid present in the oil, and this should not be confused with mineral acid, as free fatty acids are a normal constituent of the so-called "fixed" or fatty oils. Free fatty acids are determined by titrating in an alcoholic solution with a standard potash solution. The "acid number" is another method of expressing free fatty acids and is the number of milligrams of caustic potash required to neutralize one gram of the fat or oil.

Acid, Picric. See Picric Acid.

Acid-Proof Cement. A cement composed of boiled linseed oil and fireclay resists most acid vapors. A tough and elastic cement is made from 1 part of crude rubber, 4 parts of boiled linseed oil, and 6 parts of fireclay. The rubber is dissolved in carbon disulphide, until a mixture of the consistency of molasses

is obtained, and is then mixed with the oil. Asphalt compositions, and compositions of melted sulphur with fillers of stone powder, Portland cement, or sand may also be used as acid-proof cements.

Acid-Proof Tank Lining. A lining for protecting tanks from the corroding effect of acids is made from a mixture consisting of 75 parts (by weight) of pitch; 9 parts of plaster-of-paris; 9 parts of ochre; 15 parts of beeswax; and 3 parts of litharge. The tanks are covered on the inside with a thick coat of this mixture.

Acid-Resisting Alloys. Some common alloys which are noted for their acid-resisting characteristics are stainless steel, nickel, Monel and Inconel. In general, stainless steels are unaffected by nitric acid, affected somewhat by the sulphur acids, and greatly affected by the halogen acids. Of the nickel alloys, Monel resists sulphuric acid best, nickel resists hydrochloric acid best, while Inconel possesses fair resistance to both of these acids.

Acid-Resisting Iron. See Duriron.

Acid Salt. In chemistry, an acid salt is a salt formed when only part of the hydrogen in the acid is replaced by the base.

Acids, Etching. See Etching Acids.

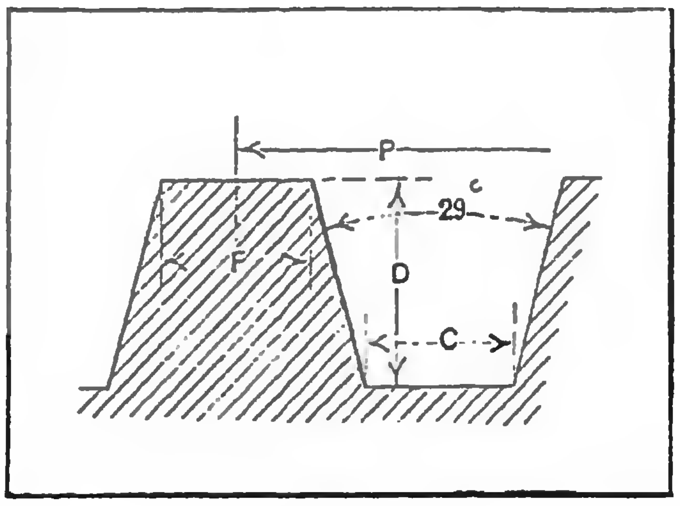
Acme Thread. The Acme thread is extensively used in preference to the square thread, especially for lead screws and similar parts. The Acme form is stronger than the square thread, and it may be cut with a die more readily than a square thread. When an Acme thread is engaged by a sectional nut like the half-nut of a lathe, engagement or disengagement is more readily effected than with a square thread; an adjustable split nut may also be used in connection with an Acme screw thread to compensate for wear and to eliminate back-lash or lost motion.

There are two basic types of Acme screw threads: American Standard Acme screw threads and American Standard Stub Acme screw threads. Two forms of American Standard Acme threads exist, each of which is used for a different application. The General Purpose form has clearance on all diameters for free movement, and may be used in assemblies with the internal thread rigidly fixed and lateral movement of the external thread limited by its bearing or bearings. There are three classes of General Purpose threads, 2G, 3G, and 4G; 2G being the preferred choice. Internal and external threads of the same class are usually used together. The other form of American Standard Acme threads, Centralizing Acme threads, comes in five classes: 2C, 3C, 4C, 5C,

and 6C; and has limited clearance at the major diameters of the internal and external threads so that a bearing at the major diameters maintains approximate alignment of the thread axis and prevents wedging on the flanks of the thread.

The American Standard Stub Acme threads are used for those unusual applications where, due to mechanical or metallurgical considerations, a coarse-pitch thread of shallow depth is required. The fit of the Stub Acme threads is generally that of the Class 2G American Standard General Purpose Acme threads.

The pitch, P, for all Acme threads is equal to the reciprocal of the number of threads per inch. The accompanying illustration gives the basic form of the Acme thread. For the General Purpose form the following relationships exist: Depth of thread, $D = 0.5\ P + \frac{1}{2}$ allowance on minor diameter (for external thread) or $D = 0.5\ P + \frac{1}{2}$ allowance on major diameter (for internal thread); basic flat at crest, $F = 0.3707\ P$ (for external and internal thread); basic flat at root for internal thread, $C = 0.3707\ P - 0.259 \times$ (major diameter allowance on internal thread); basic flat at root for external thread, $C = 0.3707\ P - 0.259 \times$ (minor diameter allowance on external thread — pitch diameter allowance on external thread). The Centralizing form is governed by the same relationships as the General Purpose but the outline of the thread form differs in that the external threads have the crest corners chamfered at an angle of 45 degrees with the axis to a minimum depth of $P \div 20$ and a maximum depth of $P \div 15$ and may have root fillets not greater than $0.1\ P$ for Classes 2C, 3C, and 4C and between $0.07\ P$ and $0.1\ P$ for Classes 5C and 6C; and the internal threads have a root fillet of $0.06\ P$, maximum. Stub Acme threads have the following relationships: Depth of thread, $D = 0.3\ P + \frac{1}{2}$ allowance on minor diameter (for external thread) or $D = 0.3\ P + \frac{1}{2}$ allowance on major diameter (for internal thread); basic flat at crest, $F = 0.4224\ P$ (for external and internal thread); basic flat at root for internal thread, $C = 0.4224\ P - 0.259 \times$ (major diameter allowance on internal thread); basic flat at root for external thread, $C = 0.4224\ P - 0.259 \times$ (minor diameter allowance on external thread — pitch diameter allowance on external thread).



Acme Thread

Acute Angle. See Angle.

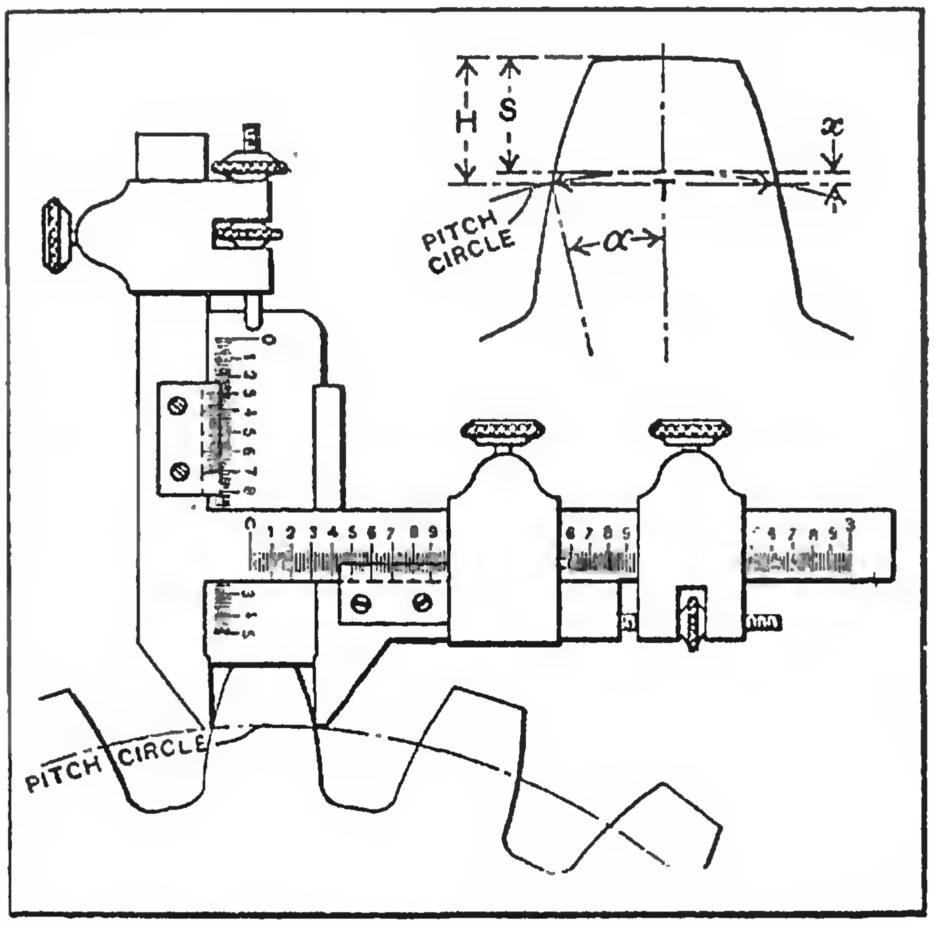
Acyclic Machines. Acyclic machines, sometimes also called *homo-polar* or, incorrectly, *uni-polar*, are direct-current machines

in which the voltage generated in the active conductors maintains the same direction with respect to those conductors.

Adamantine Boron. A crystalline form of the chemical element *boron.* It has a luster and hardness only slightly inferior to that of the diamond.

Adapter. The term "adapter" is commonly applied to any device for holding a milling cutter or arbor, which, without an adapter, would not fit into the spindle hole or onto the spindle "nose," as the case may be. For example, the standard taper for milling machine spindles is 3½ inches per foot, and the largest diameter of a No. 50 taper is 2¾ inches. If the comparatively small shank of an end-mill is to be held in this spindle, an adapter must be used. The outside of this adapter fits into the machine spindle, and a hole in the center has the same taper as the shank of the end mill. This term adapter may also be applied to work-holding or other devices which serve as an intermediate supporting member.

Addendum. The addendum of a gear tooth is the distance (S in illustration) from the pitch circle to the top of the tooth. In standard diametral pitch gearing having full-depth teeth, the addendum is equal to 1 divided by the diametral pitch. The addendum of the American Standard stub teeth, equals 0.8 divided by the diametral pitch. The *corrected addendum* is the perpendicular distance measured from the chord across the tooth at the pitch circle to the top of the tooth, as shown at H in the illustration. This distance is used when measuring the thickness of gear teeth at the pitch line by gear-tooth calipers, as indicated. When a gear tooth is measured in this way, it is the chordal thickness T that is obtained, instead of the thickness along the pitch circle.



Checking Size of Gear Tooth by Measuring Chordal Thickness

If a = one-half of the angle subtended from the center of

the gear by one gear tooth (see illustration); N = number of teeth in gear; T = chordal thickness of tooth at pitch line; and R = pitch radius of gear; then:

$$a = 90° \div N; \qquad T = 2R \times \sin a.$$

The height x of the arc equals 1 minus the cosine of angle a, multiplied by the pitch radius of the gear, or, expressed as a formula, $x = R\ (1 - \cos a)$. The vertical scale of the caliper is set to dimension H or x + addendum S.

Adhesion and Friction. Friction should not be confused with "adhesion," which not only resists the motion of one body upon another, but tends to hold the two together so that they cannot be separated. Adhesion is independent of the pressure between the bodies, while friction increases with the pressure Moreover, the smoother the rubbing surfaces the greater is the adhesion but the less is the friction; two perfectly smooth surfaces, if such were possible, would be frictionless, while the adhesion between them would be very great, as in the case of precision gage-blocks. Lubricants increase the adhesion and diminish the friction. When the pressure between two bodies is small, the adhesion forms a considerable part of the resistance, and, as the pressure increases, it becomes proportionately less, since adhesion does not increase with the pressure. At ordinary pressures, the effect of adhesion can generally be neglected, and the whole resistance considered as friction. The coefficient of friction of solid rubber tires on cement and vitrified brick roads is about 0.6, while that of pneumatic tires under similar conditions is 0.5. The coefficient of adhesion is greater than that of friction, and incidentally this partly explains why an automobile stops more rapidly when the wheels are kept moving than when they are locked; hence the increased danger when a car skids if the rear wheels are locked by the brakes.

Adhesion, Gage-Block. See Gage-block Adhesion.

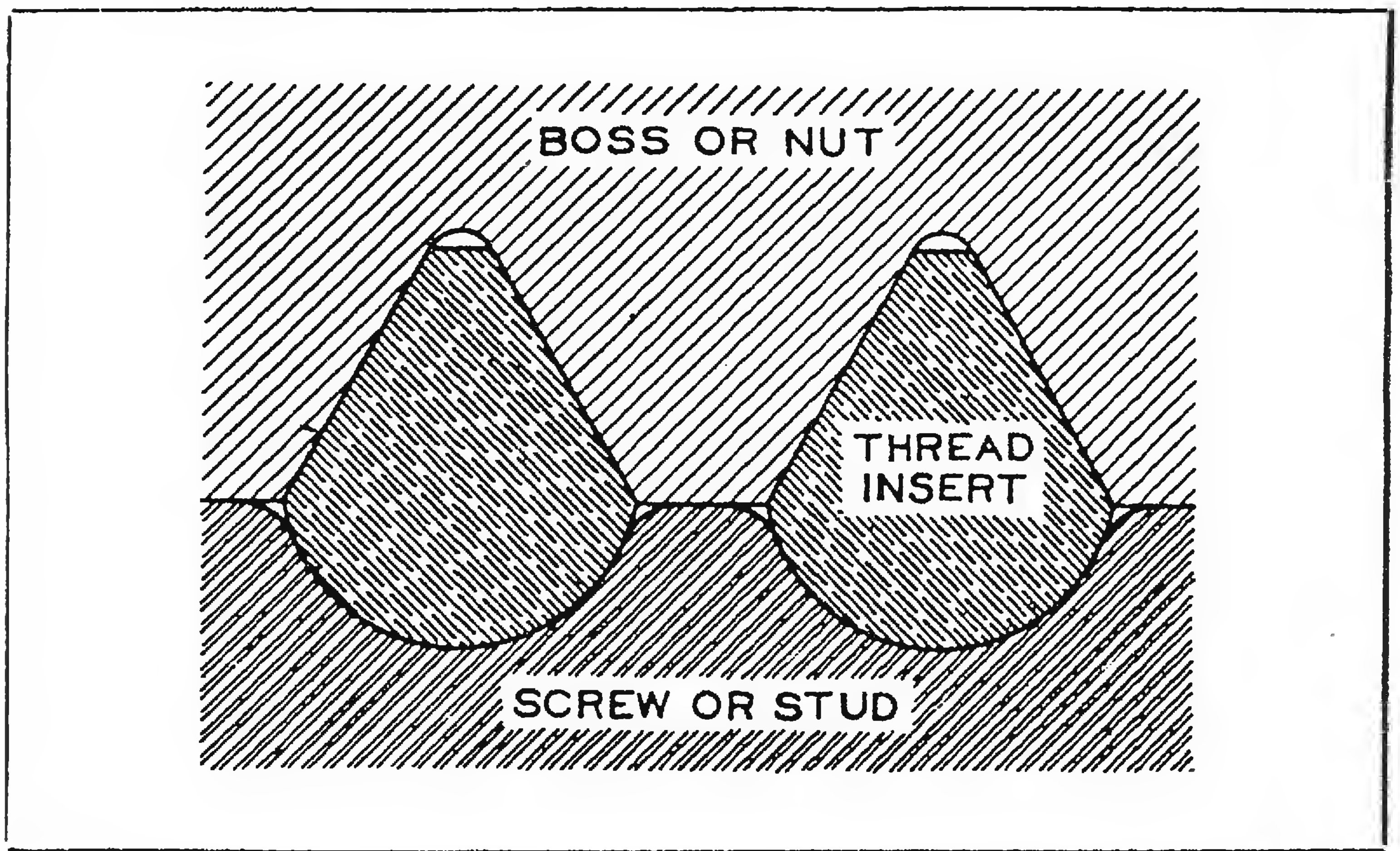
Adiabatic Curve. A curve used in a diagram to show the condition under which a gas, such as air, is compressed or expanded in adiabatic compression.

Adiabatic Expansion and Compression. Adiabatic expansion means that heat is neither added nor taken away during the expansion of air or gases; hence such expansion is accompanied by a reduction in temperature. Inversely adiabatic *compression* is accompanied by a rise in temperature. The pressure during adiabatic expansion falls faster than with isothermal expansion and rises faster for adiabatic compression than for isothermal compression. See also Isothermal Expansion and Compression.

Admiralty Metal. A name used for a number of alloys having the property of resisting the action of sea water, and used for parts of engines and machinery on board ships. One alloy consists of 87 per cent of copper, 5 per cent of zinc, and 8 per cent of tin. Another alloy, used for surface condenser tubes exposed to sea water, is composed of 70 per cent of copper, 29 per cent of zinc, and 1 per cent of tin.

Aerometer. Instruments for weighing air or for ascertaining the density of air, gases, or fluids are generally known as *aerometers.* The barometric aerometer is an instrument which consists of a vertical U-tube with open ends, mounted upon a stand in such a manner that it can be used for measuring the relative specific gravities of liquids. The method in which it is used is as follows: Water is poured into one branch of the tube, and the oil or liquid, the specific gravity of which is to be measured, is poured into the other. The vertical parts of the tube are provided with graduations. If it is found, for example, that 9 inches of water balances 10 inches of oil, then the relative specific gravities are as 10 to 9 or the specific gravity of the oil is 0.9.

Aero-Thread. The name "Aero-thread" has been applied to a patented screw thread system that is especially applicable in cases where the nut or internally threaded part is made from a



The Basic Thread Form Used In the Aero-Thread System

soft material, such as aluminum or magnesium alloy, for the sake of obtaining lightness, as in aircraft construction, and where

the screw is made from a high-strength steel to provide strength and good wearing qualities.

The nut or part containing the internal thread has a 60-degree truncated form of thread (See illustration). The screw, or stud, is provided with a semi-circular thread form, as shown. Between the screw and the nut there is an intermediary part known as a thread lining or insert, which is made in the form of a helical spring, so that it can be screwed into the nut. The stud, in turn, is then screwed into the thread formed by the semicircular part of the thread insert.

When the screw is provided with a V-form of thread, like the American Standard, frequent loosening and tightening of the screw would cause rapid wear of the softer metal from which the nut is made; furthermore, all the threads might not have an even bearing on the mating threads. By using a thread insert which is screwed into the nut permanently, and which is made from a reasonably hard material like phosphor bronze, good wearing qualities are obtained. Also, the bearing or load is evenly distributed over all the threads of the nut since the insert, being in the form of a spring, can adjust itself to bear on all of the thread surfaces.

Afterblow. That part of the basic Bessemer process during which the phosphorus is oxidized and removed.

Aging. A heat-treating term which is defined as a change in a metal by which its structure recovers from an unstable condition produced by quenching or by cold working. The change in structure consists in precipitation, of a constituent, often submicroscopic, and is marked by a change in physical properties. Aging which takes place slowly at room temperature may be accelerated by a slight increase in temperature.

It is also a term used to express the increase in hysteresis loss in the core laminations of electrical machines. See Hysteresis.

Aich Metal. Aich metal is an alloy of about 38 per cent zinc, 60 per cent copper, and 2 per cent iron. Sometimes the iron percentage is only 1.5 per cent. It is malleable at a red heat and can be hammered, rolled, or drawn into fine wire. The metal has been used as a material for cannons. The tensile strength is about 50,000 pounds per square inch; the addition of a small percentage of iron increases the strength perceptibly. At temperatures of from 200 to 1000 degrees F., Aich metal is about 50 per cent stronger than brass of about the same composition, but without the iron. The strength of Aich metal at 200 degrees F. is about 45,000 pounds per square inch; at 500 degrees F., 30,000 pounds per square inch; and at 900 degrees F.,

10,000 pounds per square inch. There are a number of alloys of a similar composition, but the principal feature of them all is the addition of iron to a copper-zinc alloy.

Air. Air is a mechanical mixture composed of 78 per cent, by volume, of nitrogen, 21 per cent of oxygen, and 1 per cent of argon. The weight of pure air at 32 degrees F., and an atmospheric pressure of 29.92 inches of mercury or 14.70 pounds per square inch, is 0.08073 pound per cubic foot. The volume of a pound of air at the same temperature and pressure is 12.387 cubic feet. The weight of air, in pounds per cubic foot, at any other temperature or pressure may be determined by first multiplying the barometer reading (atmospheric pressure in inches of mercury) by 1.325 and then dividing the product by the absolute temperature in degrees F. The absolute zero from which all temperatures must be derived in dealing with the weight and volume of gases, is assumed to be minus 459.2 degrees F. Hence, to obtain the absolute temperature, add to the temperature observed on a regular Fahrenheit thermometer the value 459.2. See also Aerometer.

Air-Balanced Hoist. See under Hoist.

Air-Break Switches. See Switches of Air-break Type.

Air Compression. Theoretically, air may be compressed under two different conditions: *Adiabatic* expansion or compression of air takes place when air is expanded or compressed without transmission of heat to or from it, as for example, if air could be expanded or compressed in a cylinder made from a material that was absolutely non-conducting to heat. *Isothermal* expansion or compression of air takes place when air is expanded or compressed with an addition or transmission of sufficient heat to maintain a constant temperature. In actual practice, neither of these two theoretical extremes is obtainable. The work required to compress air isothermally is considerably less than the work required for compressing air adiabatically; the work required for air compression in actual practice is a medium between the work that would be required for either of the two theoretical conditions. See Isothermal Expansion and Compression.

Air Compression, Multi-Stage. For the higher pressures air is compressed in *stages* and cooled between each stage. Single-stage compression is recommended for pressures up to about 50 or 60 pounds (absolute) per square inch; two-stage, for from 50 to 500 pounds; three-stage, for from 500 to 1000 pounds; and four-stage, for higher pressures. The principal reasons for multi-stage compression are: the saving in power by cooling the air

as it passes from one cylinder to the next; increased safety with regard to explosion; reduced strain on the compressor; better steam economy in the case of direct-acting steam-driven machines, owing to a better distribution of the load; more effective cylinder lubrication, due to lower air temperatures; greater volumetric efficiency, because the "clearance air" in the first cylinder, being at a lower pressure, does not expand so much on the return stroke, thus allowing an earlier admission of free air to the cylinder; and finally, the delivery of drier air to the receiver, owing to precipitation during the cooling process between the stages.

Air Compression Terms. The *displacement* of an air compressor is the volume displaced by the net area of the compressor piston. The *capacity* is the actual amount of air compressed and delivered, expressed in free air at intake temperature and at the pressure of dry air at the suction; it should be expressed in cubic feet per minute. *Volumetric efficiency* is the ratio of the capacity to the displacement of the compressor. *Compression efficiency* is the ratio of the work required to compress isothermally all the air delivered by an air compressor to the work actually done within the compressor cylinder, as shown by the indicator cards, and may be expressed as the product of the volumetric efficiency, the intake pressure, and the hyperbolic logarithm of the ratio of compression, all divided by the indicated mean effective pressure within the air cylinder or cylinders. *Mechanical efficiency* is the ratio of the air indicated horsepower to the steam indicated horsepower in the case of a steam-driven machine, and to the brake horsepower in the case of a power-driven machine. *Over-all efficiency* is the product of the compression efficiency and the mechanical efficiency.

Air Compressor. An air compressor may be defined as a machine used for increasing the pressure of air or other gas from a lower to a higher stage by reducing the volume of air or gas or compressing it into a smaller space. Usually, in air-compressor practice, the lower or initial pressure is the atmospheric pressure, while the higher or terminal pressure is fixed by the requirements in each particular case, and may be anywhere from 10 to 30 pounds gage pressure per square inch, in blowing engine practice; from 80 to 100 pounds per square inch for rock drills, pneumatic tools, etc., up to from 1500 to 2000 pounds per square inch, or even higher, for special purposes. Compressors are generally provided with a piston working in a cylinder in which the compression takes place. To a certain extent, the compression of air in the cylinder of a compressor is the reverse of the expansion of steam in the cylinder of an engine. In the case of

the former, work is expended upon the air, heat is generated, the pressure increased, and the volume reduced, while with steam, work is done, heat disappears, the pressure is reduced, and the volume increased.

Compressed Air Cooling Methods: Various plans for taking away the heat during compression, such as injecting a spray of water into the cylinder, circulating cooling water through the piston and around the heads and cylinder barrel, etc., have been tried. The use of the cooling spray, or so-called "wet-compression," has long since been abandoned, as has also the plan of circulating water through the piston, for the disadvantages more than offset the possible gains. Cylinder heads and barrels are water-jacketed, not so much on account of the heat that can be taken from the air as to keep the cylinder cool enough for proper lubrication. The most effective means for taking away the heat of compression and reducing the amount of power required consists, however, in dividing the compression into two or more stages, depending upon the terminal pressure desired, and cooling the air as much as possible between stages by means of suitable cooling apparatus, the water-jacketing of the cylinders and heads being retained for the reason mentioned.

Air Compressor Capacity. The capacity of a compressor is expressed in the cubic feet of *free air* which may be compressed to a given higher pressure in a unit of time. The term "free air" means air at atmospheric pressure, and is commonly taken at 60 degrees F. In designing an air compressor, it is generally required to work out the design for a given volume of air per minute at a given pressure. As compressors are usually rated in cubic feet of free air, it is often necessary to reduce the required volume of compressed air to its equivalent volume of free air. This may be done by dividing the volume of compressed air by the volume of 1 cubic foot of free air at the higher pressure.

Example: A compressor is required to furnish 100 cubic feet of air per minute at a gage pressure of 80 pounds per square inch. What should be its rating in free air?

The volume of 1 cubic foot of free air at 80 pounds gage pressure is 0.267 cubic foot. Therefore, the equivalent free air required by the compressor is:

$$\frac{100}{0.267} = 375 \text{ cubic feet per minute.}$$

Air Compressor Rating. Compressors are often rated upon piston displacement without regard to volumetric efficiency. The actual capacity under working conditions should be considered. The volumetric efficiency is the ratio of the actual volume of air taken into the cylinder per stroke, to the piston displacement,

and it varies with the amount of clearance and the terminal pressure. This efficiency is usually 90 per cent or over in compressors of approved design.

Air-Depolarized Cell. An air-depolarized cell is a special type of dry cell designed for constant voltage, closed circuit duty (in contrast with the ordinary dry cell which has a varying voltage and is usually suitable only for intermittent service). Instead of depending upon metallic oxides to supply oxygen for depolarization, this cell is continuously depolarized by air absorption.

Air Gages. Air gages are particularly adapted for measuring holes and bores. They are also used to measure outside diameters and to check conditions of concentricity, squareness, and flatness.

All air gages require a reasonably steady source of compressed air. It may be taken, usually through a reducing valve, from a factory air line or it may come from a separate, special air compressor. Air gages require from about 30 to 80 pounds per square inch pressure and the air supply should be filtered or cleared in some manner so that it is free of dirt, grit, oil and excess moisture.

To understand the principle of air gage action, refer to the schematic diagram in Fig. 1. The compressed air first goes

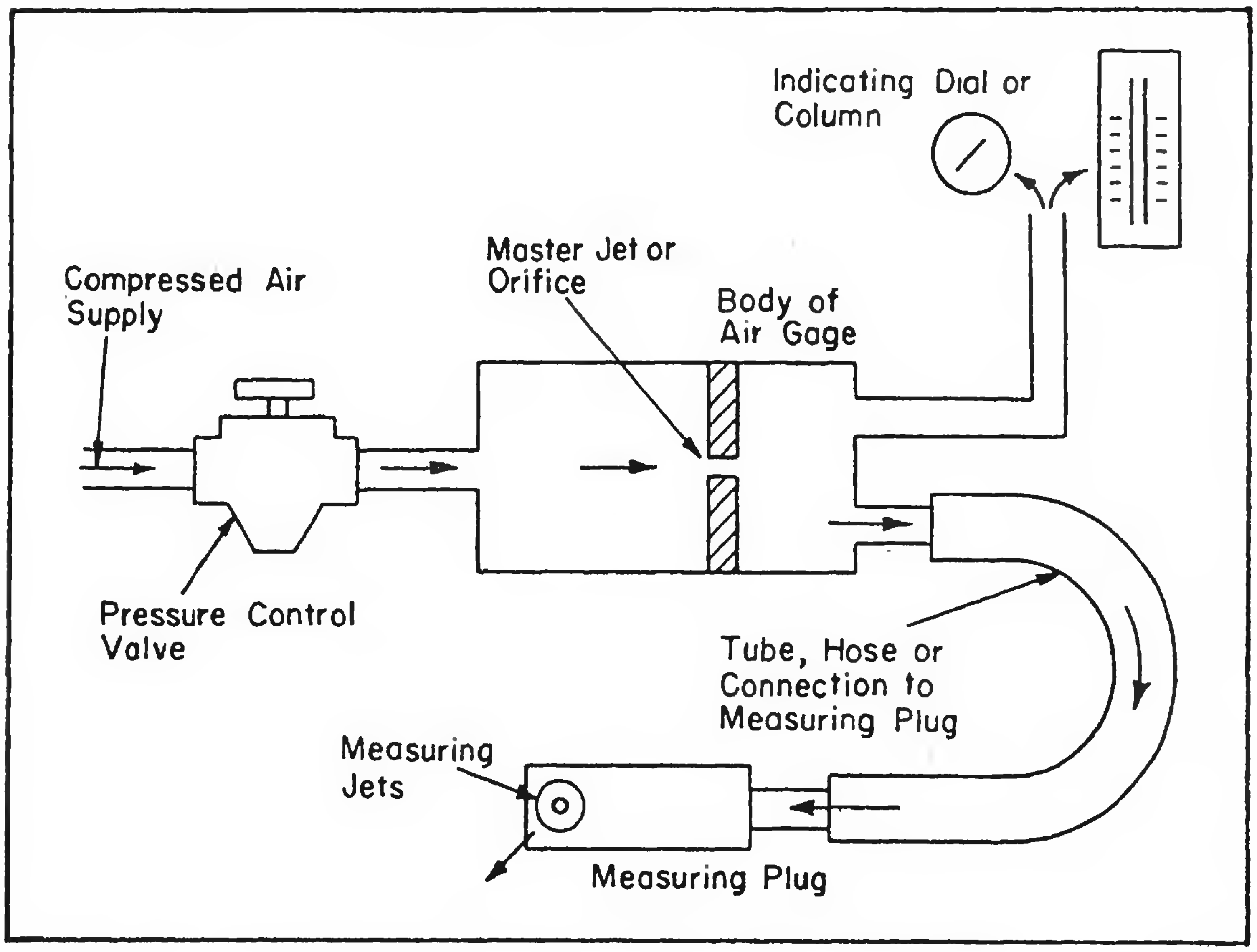


Fig. 1. Schematic Diagram Showing the Basic Elements of an Air Gage

through a so-called master jet, which is essentially an orifice or hole with a precisely controlled inside diameter, placed in the line of flow. The master jet imposes a decided restriction on the free flow of the air and builds up a steady base pressure which, depending on the make of air gage, may or may not show on the indicating device.

The air then travels along through tubes, if the measuring plug is attached to the main frame of the air gage, or through plastic hose to the measuring plug, if the latter is to be more or less portable.

Measuring plugs for air gages are made of hardened steel. frequently they are chromium plated; in many cases they are equipped with carbide wear liners. In general, they closely resemble conventional inside diameter plug gages. Before the plug is hardened, however, the air passages are drilled in it and the hardened "calipering jets" are inserted. A schematic of a measuring plug embodying a handle is shown in Fig. 2.

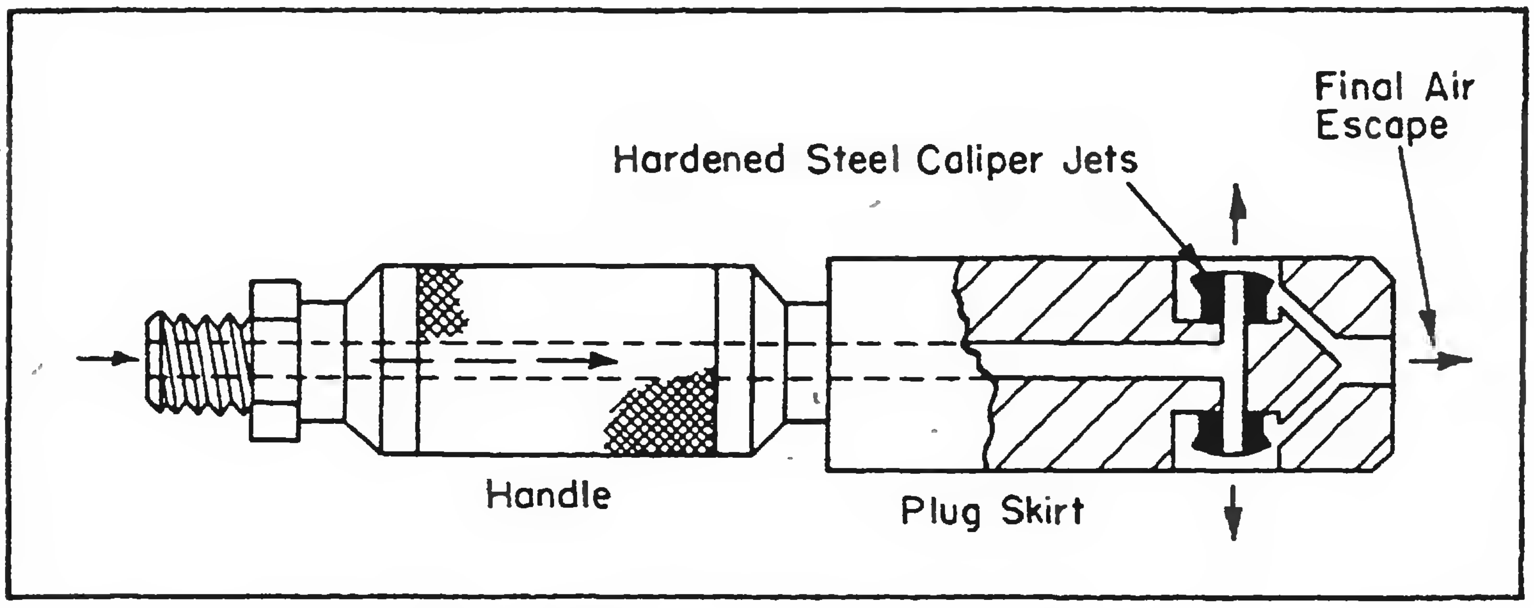


Fig. 2. Details of a Measuring Plug

The plug diameter is usually anywhere from 0.0005 to 0.003 inch under that of the holes to be measured.

As the plug is introduced into the workpiece hole, the air, moving freely away from the jets is deflected by the walls of the workpiece. Since the direction of air flow has been changed, back pressure immediately builds up and increases the pressure in front of the master jet or orifice, causing the indicator to register greater pressure.

The smaller the inside diameter of the workpiece, the closer its walls come to the jets, the more abrupt the deflection of the air (there is an effect of a harder bounce off the workpiece wall) and the greater the general restriction of its escape. Consequently the back pressure is greater and the indicator registers the decrease in diameter literally by a higher pressure reading. If the inside of the workpiece is greater, the whole effect is

reversed, and if the inside diameter of the workpiece exceeds the outside diameter of the plug by too much, the back pressure created is too small to register on the indicator.

The air gage takes advantage of the fact that minute differences (down to 0.000005 inch) in the internal diameters of workpieces will affect the back pressure sufficiently so that the pressure change can be amplified on the indicating mechanism —a difference of 0.0001 inch in workpiece I.D. showing up as about a ¼-inch movement on the indicator dial or column.

Air gages can be set up with a valve manifold and a group of air plugs for checking different size drilled and reamed holes on a particular job. Air gage manufacturers also supply adjustable bore gage heads which attach to an air gage, and by means of which a large variety of hole sizes, from ¼ inch to 8 inches, can be checked with precision.

The addition of small air cartridge devices to air gaging equipment has helped to solve measurement problems in which neither indicators nor air plugs could be used.

Air gaging is used in selective assembly by size to match cylinders and holes—shafts and bearings—to any desired fit. For this use air gaging equipment can be made up into a "matching gage" with a manifold connector and a special internal circuit which ties simultaneous I.D. and O.D. measurements together with the meter. The diameter of the hole is sensed on one unit—usually a plug—while simultaneously the O.D. of a shaft is being sensed in, usually, an air ring. The two measurements are so interconnected through special internal air circuitry that the meter registers only the *difference* in the two sizes.

Air gaging is also used for measurements to tolerances closer than 50 millionths with corresponding meter dial or column scale divisions of 0.000020 inch, 0.000010 inch or 0.000005 inch respectively.

Another technique in air gaging, called fork gaging, is used in internal grinding where it continuously registers the change in an inside diameter as the grinding proceeds. A fork gage is yoke- or U-shaped, so formed and dimensioned that it can occupy the crescent shaped area between the work and the wheel. As shown in Fig. 3, air is fed from the air gage through air passages in the yoke to a pair of sensing jets, one at each tip of the fork. The air fork is usually clamped in some sort of special design hinge device so that it can readily be flipped into gaging position after setup or readily retracted. Such a jig locates the fork on the hole center line, without the fork touching the sides of the hole; thus assuring accurate measurement and no burnishing. The jig also permits longitudinal adjustment of the gage.

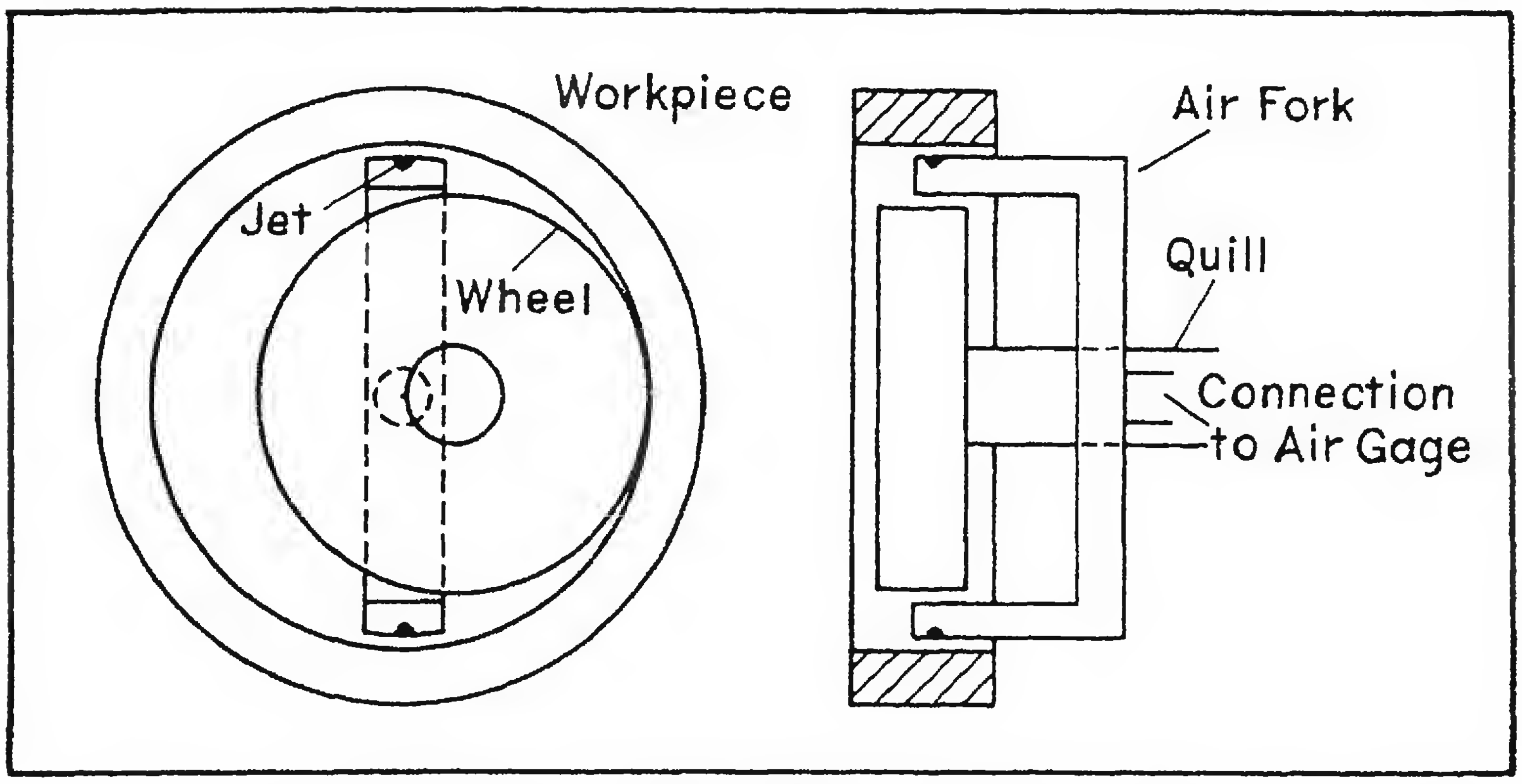


Fig. 3. Diagram of the Fork Gage Principle

Air-Hardening Steel. The origin of modern high-speed steels may be traced back to a discovery by Robert F. Mushet in 1868. Experiments were being made with the use of manganese in the production of Bessemer steel, and at first there was no idea of improving tool steel. During these experiments it was discovered that one of the bars of steel had the property of hardening after being heated, without quenching or cooling it rapidly in the manner required to harden carbon steel. This steel, which was afterwards known as mushet or self-hardening steel, was found to contain tungsten. The newly discovered steel which possessed the property of hardening when allowed to cool slowly without quenching, proved to be harder than steel which was quenched in the usual way. This discovery of self-hardening or air-hardening steel, as it was also called, led to numerous experiments with different elements in various combinations and, as a result, an alloy steel was obtained which was superior to carbon steel for rapid machining operations. The discovery was made later that the quality of the steel could be improved if the cutting end were reheated and cooled in an air blast, instead of being allowed to cool by simply exposing the heated steel to the atmosphere. An analysis of a typical mushet self-hardening steel showed the following composition: Tungsten, 5.441 per cent; chromium 0.398 per cent; carbon, 2.15 per cent; manganese, 1.578 per cent; silicon, 1.044 per cent.

Air, Moisture in Compressed. See Compressed Air, Moisture in.

Air or Vacuum Pump. An air pump or "vacuum pump" is used for exhausting or removing air or other gases from a closed vessel or container, thus producing a partial vacuum. Pumps of

this class are extensively used in connection with steam engines and turbine condensers and other condensing apparatus. Air pumps for condenser service may be divided into two general classes known as "wet-air pumps" and "dry-air pumps," according to the conditions under which they operate. Air pumps of the *wet type* handle both air and the water of condensation, and those used with surface and jet condensers are practically the same, except in size, the volume of water handled being much less in the case of the former, as a separate pump is employed for the cooling water. Pumps of the *dry type* have come into use with the advent of the steam turbine, where a high vacuum is required, and are usually of the flywheel or the centrifugal type. They are connected with the condensing chamber in such a manner as to withdraw air only, the condensation being removed by a separate "hot-well" pump. This arrangement makes it possible to use valves designed especially for air, and thus maintain a considerably higher vacuum.

Air Receiver. Air receivers are used in connection with air compressors for the purpose of storing the air, so as to maintain a constant pressure and equalize the pulsations in the air as it comes from the compressor. The receiver also serves the purpose of collecting the water and grease held in suspension by the compressed air, and cools the air before it enters the transmission system.

The air receiver plays an important part in obtaining the highest efficiency and most economical operation of a compressed air installation. It is essential that the cubic capacity of the receiver be in the right proportion to the capacity of the compressor. The receiver should have a capacity from 15 to 20 per cent of the free air capacity of the compressor (per minute), but, in large installations, the percentage is sometimes lower, running down to 10 per cent. To obtain good results, the receiver should be placed as near as possible to the compressor, and, in any case, not more than 50 feet distant. Receivers may be placed in either a vertical or horizontal position, the vertical being preferred, in most cases, owing to the economy in floor space thus obtained. In many cramped installations, the receiver is suspended from the ceiling by means of hangers, or on the wall by means of brackets.

The inlet and outlet openings of an air receiver should not lie in a straight line opposite each other, as a through current would interfere with efficient cooling and depositing of the moisture. The usual practice is to have the air enter at the top of the receiver and have it discharge at the side near the bottom where the air is cooler, thus causing a change in the direction of flow and allowing more efficient cooling and depositing of the moisture.

The receiver, if the capacity is sufficient, prevents any appreciable rise or fall of pressure due to the discharge of air, and absorbs all pulsations. It acts as a reservoir of power only to a limited extent.

Air Resistance. The resistance of air to the moving parts of machinery often is not considered. Yet still air may offer considerable resistance to parts having a certain form and moving at high speed, as is evidenced by the airplane which is lifted by the action of the propeller and planes against air resistance. Covering large rapidly revolving flywheels on both sides with light plates has a marked effect in reducing the air resistance of the spokes. This is rarely done, however, because of its first cost and appearance. In calculating the power necessary to move a vehicle or projectile, consideration must be given to the resistance of either still air or wind against which it is forced. The wind exerts pressure on sloping roofs and the sides of all buildings, towers, bridges, or any other structure, and they must be able to resist collapsing or overturning because of this force. Even wires have considerable wind resistance, which is increased greatly when they are covered with sleet.

Air, Saturated. Saturated air is air containing the maximum amount of water vapor possible at any particular temperature and barometric pressure. Atmospheric air usually contains a smaller amount of moisture (water vapor) than saturated air. The amount of moisture in atmospheric air relative to the amount of moisture in saturated air (humidity) is reported daily by the United States Weather Bureau, as well as the mean temperature and the barometric pressure. Variations in the amount of moisture modify the specific heat of air, and therefore the specific heat of dry air at a given temperature should be corrected for the actual humidity condition.

Ajax Metals. A group of copper-lead-tin alloys some of which also contain phosphorus, iron and nickel that are used for bearing purposes. Two alloys containing only tin and lead in proportions of 50-50 and 40-60, respectively, are used as solders. Another Ajax metal, called Ajax manganese bronze, contains 57 per cent copper, 40 per cent zinc, 3 per cent manganese, and a hardener. It is used for its strong, tough, corrosion resistant properties in the making of valve stems, propellers and nuts.

Alclad Metals. A group of wrought aluminum metals that have coatings of high-purity aluminum or of an aluminum that is different from the core alloy in composition. These coatings provide protection against corrosion.

Alcohol Anti-Freezing Mixtures. See Anti-freezing Mixtures.

Algebra. That part of mathematics known as *algebra* may be defined as a generalized arithmetic. In arithmetic, the answer to a specific problem is always required. In algebra, a general solution is usually desired, which may be applied to all problems of a similar character. A quantity in mathematics is any number involved in a mathematical process, and, in algebra, letters are used instead of figures to represent numbers or quantities. The use of letters or symbols in place of the actual numbers simplifies the solution of mathematical problems and makes it possible to obtain the result more rapidly and accurately. The symbols used in algebra are mainly the letters of the alphabet. Ordinarily, the first letters of the alphabet are used to represent known quantities, and the last letters, unknown quantities. As a rule, small letters rather than capital letters are employed.

Alkali. In chemistry, a base that will dissolve in water is known as an alkali. See Base.

Alkaline Battery. See Edison Battery.

Alkaline Quenching Baths. See Quenching Baths, Alkaline.

Alligation. Alligation or "the rule of mixtures" are names applied to several rules of arithmetical processes for determining the relation between proportions and prices of the ingredients of a mixture and the cost of the mixture per unit of weight or volume. For example, if an alloy is composed of several metals varying in price, the price per pound of the alloy can be found as in the following example: An alloy is composed of 50 pounds of copper at 14 cents a pound, 10 pounds of tin at 29 cents a pound, 20 pounds of zinc at 5 cents a pound, and 5 pounds of lead at 4 cents a pound. What is the cost of the alloy per pound, no account being taken of the cost of mixing it? Multiply the number of pounds of each of the ingredients by its price per pound, add these products together, and divide the sum by the total weight of all the ingredients. The quotient is the price per pound of the alloy.

The foregoing example would be worked out numerically as follows:

$$50 \times 14 + 10 \times 29 + 20 \times 5 + 5 \times 4 = 700 + 290 + 100 + 20 = 1110$$

Total weight of metal in alloy $= 50 + 10 + 20 + 5 = 85$

Price per pound of alloy $= \dfrac{1110}{85} =$ 13 cents, approximately.

Allowance. The term "allowance," as applied to the fitting of machine parts, means a difference in dimensions prescribed in order to secure classes of fits; in other words, allowance is the amount required either above or below a nominal size, so that a certain class of fit is obtained, as, for example, a running fit, a forced or pressed fit, etc. For instance, if the hole in a crank disk is 3 inches in diameter and the shaft is made 3.005 inches in diameter in order to secure a forced fit, the 0.005 inch would represent the *allowance* for that part. The terms "allowance" and "tolerance" are often—but incorrectly—used interchangeably; according to common usage "tolerance" is a difference in dimensions prescribed in order to allow unavoidable imperfections of workmanship.

Alloy. An alloy is an intimate mixture of two or more metals melted together. Mixtures of this kind are generally mechanical in their nature, but are homogeneous; in some cases, they may form chemical compounds. As a rule, when two metals are melted together to form an alloy, the substance formed is, for all practical purposes, a new metal. Brass, bronze, and German silver are examples of well-known alloys.

Alloys, Acid-Resisting. See Acid-resisting Alloys.

Alloys, Die-Casting. See Die-casting Alloys.

Alloys, Non-Ferrous. Alloys may be divided into ferrous and non-ferrous; the former contain iron as their chief component, while the latter do not. The most important of the ferrous alloys are the alloy steels. Of non-ferrous alloys, the bronzes, brasses, aluminum, zinc, and copper alloys are the most important. *Bronze* is an alloy consisting of copper and tin in variable proportions, in which copper is the chief component. *Brass* is an alloy consisting of copper and zinc in variable proportions, with copper as the chief component. Besides bronze and brass, a classification of non-ferrous alloys that is used, but not universally adhered to, defines an alloy consisting of more than two metals with copper as the chief component as a *composition.* Thus a bronze composition is an alloy of copper and tin with one or more variable components, but in which tin is the chief minor component; a brass composition is an alloy of copper and zinc combined with one or more other components, but in which zinc is the chief minor ingredient. In general usage, brass and bronze compositions are frequently known simply as "brass" and "bronze."

Alloy Steel. A steel containing some metallic element other than iron and carbon, such as nickel, chromium, tungsten, vanadium, etc., is generally known as an "alloy" or "special" steel.

These various metals, when added to steel in certain (generally small) percentages, add distinct properties; they especially increase the hardness and the toughness of the steel. Various alloy steels are treated separately under their respective headings.

Almandite. See Garnet.

Alnico. Alloy containing iron, aluminum, nickel, and cobalt. Usually cast and finished to shape by grinding. Magnets made from this alloy have remarkable power and will lift sixty times their own weight. Applied to a variety of electrical uses, including blow-outs for relays, holding in magnets for large switches, special timing relays, and various control devices. Small motors and control devices formerly operated by electromagnets can be operated by Alnico permanent magnets at a great saving in cost.

Alowalt. The trade name "Alowalt" is used by the Waltham Grinding Wheel Company for aluminum-oxide products. See Aluminum Oxide.

Aloxite. The trademark "Aloxite" is used by the Carborundum Company for abrasives or other products made from aluminum oxide. See Aluminum Oxide.

Alsimag 222. Machinable, ceramic material with low dielectric loss at high frequencies which can be used at temperatures up to 2500 degrees F. Available in round or tubular form and in disks or plates; special shapes also can be supplied. Because of abrasive nature, must be machined with carbide tipped tools. Especially suitable for building working models. Also suitable for application in electronic field.

Alternating Current. An alternating electrical current is a current that alternates regularly in direction and, unless otherwise specified, the term "alternating current" refers to a periodic current with successive waves of the same shape and area. Alternating current has the advantage over direct current in that simpler generating machines, and generally more rugged motors, may be used; but the chief advantage is that it is possible to obtain and use very much higher voltages than can be easily obtained or used with direct current. Alternating current is, therefore, used whenever distant transmission of electric power is necessary.

Alternating-Current Generator. See Generator, Alternating-current.

Alternation. An *alternation* is an oscillation of an electric or magnetic wave from a zero to a maximum value and back to zero again. It may be positive or negative, positive alternations generally being indicated above the zero reference line, and the

negative, below. There are two alternations to each cycle. See Cycle, Alternating Current.

Alumina. Alumina or aluminum oxide, chemical formula Al_2O_3, occurs in nature in the mineral *corundum*. The alumina in corundum is the abrasive material which makes it useful for abrasive purposes. The abrasive material in *emery* is also alumina. See also Aluminum Oxide.

Aluminum. Aluminum is widely distributed in nature in combinations, especially as silicates, but is never found in the free state. Alumina or aluminum oxide, from which aluminum is obtained, was first discovereed by Marggraf, in 1754. The metal itself, however, was first discovered by Wohler, in 1828, but it was not until about 1883 that aluminum was produced on a commercial scale. Now aluminum is produced by electrical means from bauxite, a hydrated oxide of aluminum ($Al_2O_3 + 2\ H_2O$). This mineral is widely distributed all over the world, but the most important places where it is found are in Alabama, Arkansas, and Georgia, and in the south of France and the north of Ireland. Aluminum is also contained in various other natural compounds, such as corundum, cryolite, and kaolin or china-clay.

Properties of Aluminum: Aluminum is a white metal having a somewhat bluish luster when polished. The specific gravity of aluminum varies from 2.5 to 2.7. When cast in the pure state, it has a specific gravity of 2.58. When rolled in bars of large section, the specific gravity is about 2.6, but, when rolled into very thin sheets, it may rise to 2.69. Commercial aluminum, however, contains impurities to such an extent that the specific gravity generally varies between 2.7 and 2.8. When in the molten state, the metal expands and the specific gravity is only from about 2.43 to 2.54. As pure aluminum is lighter than the commercial product, a careful determination of the specific gravity is a good indication of the purity of the metal tested.

Aluminum is a very ductile and malleable metal; it can be made into sheets 0.000025 inch thick and drawn into wires 0.004 inch in diameter. Sheets as thin as mentioned can only be obtained by beating like gold-leaf, but sheets may be rolled down to a thickness of 0.0005 inch. The melting point of aluminum is at 1218 degrees F. (659 degrees C.). The coefficient of linear expansion, by heat, is 0.0000125 per each degree F. The mean specific heat between 32 and 212 degrees F. is 0.227, and the latent heat of fusion, 28.5 B.T.U. Aluminum is a good conductor of heat and is surpassed, in this respect, only by silver, copper, and gold. Its conductivity of heat is equal to 31 per cent of that of silver. The heat transmitted in British thermal units per second, through aluminum 1 inch thick, per square

inch of surface, for a temperature difference of 1 degree F., is 0.00203 B.T.U.

Aluminum is a good conductor of electricity, its electrical conductivity being about 60 per cent of that of copper for equal volumes, or about double that of copper for equal weights. Aluminum is not magnetic. Pure aluminum, chemical symbol Al, and atomic weight 27.1, has a hardness on the Mohs scale of 2.5, this degree of hardness making it just a little too hard to be scratched by the finger nail. Impurities, however, harden the metal to a considerable extent, even when present in small quantities, and the purity of the metal is roughly estimated by the ease with which it can be cut with a steel knife. The surface of aluminum is hardened, to a very great degree, by cold-drawing or rolling, so that the surface may obtain a hardness equal to that of brass. Aluminum alloys are distinguished by their low specific gravity and high tensile strength.

Aluminum Alloys. While aluminum is valuable for many light-weight machine parts, it is soft and lacking in tensile strength and rigidity for many purposes. In order to increase the strength, and at the same time retain the valuable property of lightness, copper, manganese, magnesium, and other elements are alloyed with aluminum in various proportions. The strength of aluminum is also increased by means of rolling, forming, or otherwise cold-working, and by heat-treatment. Wrought-aluminum alloys may be obtained in several work-hardened tempers. The alloys used for structural parts in aircraft are, in most cases, heat-treated. Aluminum alloys are obtainable either in the wrought form or cast form. Both of these general types are further classified either as heat-treatable or non-heat-treatable. The first aluminum alloy adapted to commercial heat-treatment contained 4 per cent of copper, ½ per cent of magnesium, and ½ per cent of manganese. This alloy was designated by the trade name "Duralumin" which was later abbreviated "Dural." The aluminum alloy "24S" which is so extensively used in aircraft construction at the present time, contains the same alloying elements as Dural but in different proportions, being about 4½ per cent copper, 1½ per cent magnesium, and 0.6 per cent manganese.

Aluminum Alloy Classification Symbols: Symbols which are in general use indicate the composition and temper of the alloy. A typical symbol would be 24S-T4, where the 24 indicates its composition, the S indicates it to be a wrought alloy and the T4 designates its temper. For wrought alloys the following alloy numeral ranges and their chief alloying elements are given: 2S—commercially pure aluminum, 3S to 9S—manganese, 10S to 29S—copper, 30S to 49S—silicon, 50S to 69S—magnesium, and 70S to 79S—zinc.

The meanings of temper designations for both wrought and cast aluminum alloys are as follows: -F means as fabricated; -O means annealed, recrystallized—wrought products only; -H means strain hardened (-H1, plus one or more digits means strain hardened only; -H2, plus one or more digits means strain hardened and then partial annealed; -H3, plus one or more digits means strain hardened and then stabilized); -W means solution heat treated—unstable temper; -T means treated to produce stable tempers other than -F, -O, or -H (-T2 means annealed—cast products only; -T3 means solution heat treated and then cold worked; -T4 means solution heat treated; -T5 means artificially aged only; -T6 means solution heat treated and then artificially aged; -T7 means solution heat treated and then stabilized; -T8 means solution heat treated, cold worked, and then artificially aged; -T9 means solution heat treated, artificially aged, and then cold worked; -T10 means artificially aged and then cold worked).

Aluminum Alloys, Cast. The S.A.E. standard cast aluminum alloys are of two types. *Type 1:* Improvement in the physical properties of Type 1 results from alloying only. *Type 2:* The properties of Type 2 that result from alloying, are further improved by heat-treatment.

In the design of patterns for the production of aluminum alloy sand castings, a shrinkage of 0.156 (5/32) inch per foot is usually allowed, although this value may vary slightly, depending upon the form and size of the casting.

S.A.E. Standard No. 300, Type 2 Alloy: This alloy is of a composition which can be made almost entirely from scrap materials and, when the iron content approaches the maximum permitted, requires that special molding conditions be satisfied in order to secure sound castings. It has been used extensively for gasoline engine pistons. A "stabilizing" heat treatment (aging of "as cast" material) is recommended in order to minimize changes in dimensions and mechanical properties due to elevated temperature service.

Composition of No. 300: Copper, 6 to 8; iron, max. 1.5; silicon, 5-6; manganese, max. 0.75; magnesium, 0.15 to 0.5; zinc, 1.0; other elements, 1.25 per cent total; remainder, aluminum.

Physical Properties: Tensile strength, 27,000 pounds per square inch and Brinell hardness (500 kg. 10 mm.), 100.

S.A.E. Standard No. 310, Type 1 Alloy: This is a general purpose alloy which develops high mechanical properties and a good

ductility when aged for several weeks at room temperature or for a short time at a slightly elevated temperature. Within the first two weeks after casting, or before artificial aging, the alloy has a high ductility, permitting severe cold deformation. Its uses are numerous but by far the most outstanding is the fact that it can be used as an alternate for S.A.E. No. 38 alloy when heat-treating facilities are not available since the alloy does not require a high-temperature solution heat-treatment. This general purpose structural casting alloy has good casting properties and can be machined easily by employing conventional machining methods.

Composition of No. 310: Copper, maximum 0.2; iron, maximum 1.0; silicon, maximum 0.25; magnesium, 0.4-0.6; zinc, 4.8-5.7; titanium, 0.1-0.3; chromium, 0.4-0.6; other elements, maximum 0.05 per cent each; remainder, aluminum.

Physical Properties: Tensile strength, 30,000 pounds per square inch; typical yield strength, 25,000 pounds per square inch; and an elongation in 2 inches, 3 per cent minimum. Its specific gravity is approximately 2.80.

S.A.E. Standard No. 320, Type 1 Alloy.—This alloy is used for carburetor cases, cast pipe fittings, and other castings requiring high resistance to corrosion. It has good mechanical properties and is easily machined.

Composition of No. 320: Magnesium, 3.2 to 4.3; manganese, max., 0.60; iron, max., 0.4; silicon, max., 0.3; copper, max., 0.10; zinc, max., 0.05; all elements other than aluminum, magnesium and manganese, max., 0.6 per cent; titanium, max., 0.2; aluminum, remainder.

Physical Properties: Tensile strength, 22,000 pounds per square inch minimum; elongation in 2 inches, 6 per cent minimum; specific gravity, about 2.64 (less than that of pure aluminum).

S.A.E. Standard No. 321, Type 2 Alloy.—This alloy is used for automobile engine pistons because of its low coefficient of expansion compared with other aluminum alloys, its hardness and resistance to wear, and its good mechanical properties at elevated temperatures. The pistons are as a rule cast in permanent metal molds but this alloy may also be used for sand castings and for other applications similar to those for Nos. 34 and 39.

Composition of No. 321: Silicon, 11.0 to 13.0; magnesium, 0.7 to 1.3; manganese, max., 0.05; nickel, 2.0 to 3.0; copper, 0.5 to

1.5; iron, max., 1.3; zinc, max., 0.1; other impurities, max., 0.2 per cent; aluminum, remainder.

S.A.E. Standard No. 322, Type 2 Alloy.—This alloy is used for water-cooled cylinder heads for automobile or aircraft engines and for similar applications requiring sound leak-proof castings produced either in sand or permanent metal molds. This alloy has excellent foundry characteristics and resistance to corrosion.

Composition of No. 322: Silicon, 4.5 to 5.5; copper, 1.0 to 1.5; magnesium, 0.4 to 0.6; iron, max., 0.5; manganese, max., 0.1; zinc, max., 0.05; titanium, max., 0.2; other impurities, max., 0.2 per cent; aluminum, remainder.

Physical Properties: This alloy can be heat-treated to improve its mechanical properties. The minimum tensile strength ranges from 27,000 to 36,000 pounds per square inch, depending upon heat-treatment, and the elongation in 2 inches, from 2 to 4 per cent minimum.

S.A.E. Standard No. 323, Type 2 Alloy.—This alloy has excellent foundry characteristics and resistance to corrosion. It is commonly used for high-strength castings which are too intricate to permit using alloy No. 38. It is also preferred where high corrosion resistance is necessary.

Composition of No. 323: Silicon, 6.5 to 7.5; magnesium, 0.2 to 0.4; iron, max., 0.5; copper, max., 0.2; zinc, max., 0.05; titanium, max., 0.2; other impurities, max., 0.05 per cent; aluminum, remainder.

Physical Properties: Tensile strength, 23,000 to 30,000 pounds per square inch minimum, depending upon heat-treatment; elongation in 2 inches, from 3 to 5 per cent minimum.

S.A.E. Standard No. 324, Type 2 Alloy.—This alloy is used for castings requiring a maximum ratio of strength to weight. It is used for some aircraft fittings, truck parts, and especially where service conditions are severe.

Composition of No. 324: Magnesium, 9.5 to 11.3; copper, max., 0.20; iron, max., 0.30; silicon, max., 0.20; other impurities, max., 0.20 per cent; aluminum, remainder.

Physical Properties: Minimum tensile strength, 42,000 pounds per square inch; elongation in 2 inches, 12 per cent minimum; specific gravity, about 2.55 compared with 2.70 for pure aluminum.

S.A.E. Standard No. 33, Type 1 Alloy.—This is widely used as a general casting alloy and for such parts as crankcases, oil-

pans, differential carriers, transmission cases, camshaft housings, cylinder heads for water-cooled automobile engines.

Composition of No. 33: Copper, 6.0 to 8.0; zinc, max., 2.2; magnesium, max., 0.05; manganese, max., 0.3; iron, max., 1.05; silicon, max., 1.0 to 3.0; aluminum, remainder. Total, all elements other than aluminum, max., 13.5 per cent.

Physical Properties: Minimum tensile strength, 19,000 pounds per square inch; elongation in 2 inches, ordinarily from 1 to 2½ per cent; specific gravity, from 2.83 to 2.86. If cast in permanent molds, the minimum tensile strength will be about 23,000 pounds per square inch.

S.A.E. Standard No. 34, Type 2 Alloy.—This alloy has been used chiefly for pistons of automobile engines (like No. 321). It is also used for camshaft bearings, valve tappet guides, and other parts requiring hardness and resistance to wear. It is used principally for permanent mold castings but is also cast in sand. Air-cooled cylinder heads for aircraft engines and valve guides and piston sleeves for Diesel engines are other examples of applications.

Composition of No. 34: Copper, 9.2 to 10.8; iron, max., 1.50; iron plus silicon, max., 2.0; magnesium, 0.15 to 0.35; manganese, max., 0.3; zinc, max., 0.2; other impurities, max., 0.3 per cent; aluminum, remainder.

Physical Properties: Minimum tensile strength, from 26,000 to 34,000 pounds per square inch for permanent mold castings. The sand cast alloy should have a tensile strength of at least 23,000 pounds per square inch, and this may be increased by heat-treatment to a minimum of 30,000 pounds per square inch.

S.A.E. Standard No. 38, Type 2 Alloy: This alloy is used for engine crankcases, and other vehicle and aircraft parts requiring high strength and light weight. It is also used for outboard motors and ship castings requiring corrosion resistance.

Composition of No. 38: Copper, 4.0 to 5.0; silicon, max., 1.2; iron, max., 1.0; manganese, max., 0.05; magnesium, max., 0.03; zinc, max., 0.05; titanium, max., 0.2; other impurities, max., 0.05 per cent; aluminum, remainder.

Physical Properties: One of three heat-treatments may be applied, depending upon properties required. Minimum tensile strength ranges from 29,000 to 36,000 pounds per square inch, depending upon heat-treatment; the elongation in 2 inches ranges from 3 to 6 per cent; specific gravity is about 2.77.

S.A.E. Standard No. 39, Type 2 Alloy.—This alloy is used for pistons and cylinder heads of aircraft engines and for other castings subjected to elevated temperatures. It may be used as cast but usually is heat-treated to develop higher physical properties or to relieve casting strains and stabilize dimensions at elevated temperatures.

Composition of No. 39: Copper, 3.5 to 4.5; nickel, 1.7 to 2.3; magnesium, 1.2 to 1.8; iron, max., 1.0; silicon, max., 0.7; other impurities, max., 0.3 per cent; aluminum, remainder.

Physical Properties: Minimum tensile strength for sand castings, 23,000 pounds per square inch which may be increased to 32,000 by heat-treatment. If cast in permanent molds, the minimum tensile strength is 26,000 pounds per square inch which may be increased to 40,000 by heat-treatment. Specific gravity is about 2.73 to 2.77, the higher values being for permanent mold castings.

Aluminum Alloys, Wrought. S.A.E. standard specifications for wrought alloys as given in the following indicate fabricated forms which are regularly manufactured. Type 1 indicates an improvement in the physical properties resulting from alloying only. Type 2 indicates that the properties resulting from alloying are further improved by heat-treatment.

S.A.E. Standard No. 201, Type 1 Alloy.—This alloy is manufactured in the form of sheets, plates, bars, rods and wire, and in the standard size of tubing specified for aircraft fuel and oil lines. The sheets are used for aircraft gasoline tanks, engine cowling, and other moderately stressed parts and for panels, roof sheets, etc., in truck and bus construction.

Composition of No. 201: Magnesium, 2.2 to 2.8; chromium, 0.15 to 0.35; aluminum, min. 96.1 per cent.

Physical Properties: In sheet form the tensile strength in the "soft" to "hard" tempers ranges from 31,000 to 39,000 pounds per square inch min.; the elongation in 2 inches varies from 3 to 4 per cent in the hard temper, and from 15 to 20 per cent in the soft temper, depending upon the thickness. The yield strength in the soft temper is approximately 14,000 pounds per square inch; in the harder tempers it averages 75 to 85 per cent of the ultimate tensile strength. The shearing strength ranges from 18,000 to 24,000 pounds per square inch for soft to hard tempers.

S.A.E. Standard No. 24, Type 2 Alloy.—This alloy, in the form of sheets, plates, tubing, bars, rods, wire, rivets, and in rolled

and extruded shapes, is replacing No. 26 to an increasing extent in the construction of aircraft because of its high physical properties.

Composition of No. 24: Copper, 3.7 to 4.9; magnesium, 1.2 to 1.8; manganese, 0.3 to 0.9; aluminum, min., 92.0 per cent.

Physical Properties: In the form of sheets, the tensile strength varies from 35,000 for soft temper to 62,000 pounds per square inch for heat-treated sheets, and the elongation in 2 inches from 12 to 18 per cent. The yield strength of a heat-treated sheet is about 40,000 pounds per square inch minimum.

S.A.E. Standard No. 26, Type 2 Alloy.—This alloy is commonly known as duralumin, dural, or 17S. It is commercially available in sheets, tubing, bars, wire, etc., and in both rolled and extruded forms, including standard structural shapes. It is used for bolts and nuts, machine screws, wood screws, rivets, forgings, screw machine products, fuel and lubrication tube fittings, etc.

Composition of No. 26: Copper, 3.5 to 4.5; magnesium, 0.2 to 0.75; manganese, 0.4 to 1.0; aluminum, min., 92.0 per cent.

Physical Properties: The minimum tensile strength of heat-treated sheets and plates is about 58,000 pounds per square inch; the yield strength, 34,000 pounds per square inch; and elongation from 6 to 18 per cent. Bars, rods, wire and structural shapes have a minimum tensile strength of 55,000 pounds per square inch and a yield strength of 32,000 pounds per square inch minimum. In the annealed condition, the tensile strength should not exceed 35,000 pounds per square inch. In the heat-treated temper the shearing strength is about 36,000 pounds per square inch.

S.A.E. Standard No. 260, Type 2 Alloy: This alloy has been used principally for the production of high-strength forgings. It is also available in the form of extruded sections.

Composition of No. 260: Copper, 3.9 to 5.0; iron, maximum 1.0; silicon, 0.5 to 1.2; manganese, 0.4 to 1.2; magnesium, 0.2 to 0.75; zinc, maximum 0.25; chromium, maximum 0.10; titanium, maximum 0.15; other elements, maximum 0.05 each and 0.15 per cent total; and remainder aluminum.

Physical Properties: Minimum tensile strength for forgings up to 4-inch thickness is 65,000 pounds per square inch, and for extrusions from 60,000 to 68,000 pounds per square inch depending upon thickness. Minimum elongation in 2 inches for forgings is 10 per cent and for extrusions, 7 per cent.

S.A.E. Standard No. 281, Type 2 Alloy.—This alloy has good mechanical properties, especially yield strength, and is capable of being formed more severely in the heat-treated (T) temper than the other Type 2 alloys. In the quenched (W) temper even more difficult forming can be done and the resulting shape can then be aged artificially to produce the heat-treated (T) temper. This alloy is used in the form of sheet and plate in bus and truck construction and also finds some use in aircraft and aircraft engines in the form of both tubing and sheet.

Composition of No. 281: magnesium, 0.8 to 1.2; silicon, 0.4 to 0.8; copper, 0.15 to 0.40; chromium, max., 0.35; titanium, max., 0.15; manganese, max., 0.15 and aluminum, 96.0 per cent.

Physical Properties: In the form of sheet, plate and tubing this alloy has the following properties: in the quenched temper (W) a minimum tensile strength of 30,000 pounds per square inch and a minimum yield strength of 35,000 pounds per square inch and in the soft temper (O) a maximum tensile strength of 22,000 pounds per square inch.

Aluminum Annealing. Correct annealing of aluminum is dependent upon both time and temperature. Frequently the length of the annealing period has a more important bearing on the mechanical properties than has the temperature. Although aluminum is distinctly a malleable metal, it frequently is necessary to anneal it two or three times during the forming of an intricate piece. The procedure is to work the piece to a certain stage, anneal it, and repeat the process until the desired shape is obtained. Sheet aluminum can be annealed most efficiently in a muffle furnace, where the heat can be obtained by radiation. If such a furnace is not available, the work may be annealed quite satisfactorily in an open fire of clean coke, over a brazier's gas hearth, or over the flame of the benzoline or gasoline blow-torch. Owing to the relatively low melting point of aluminum, which is approximately 1218 degrees F., great care must be taken during annealing to prevent the metal from melting. The annealing temperature varies from 700 to 900 degrees F., depending on the thickness of the metal and the length of time that it is subjected to the heat. Tests have shown that short exposures in the annealing temperature, ranging from three to thirty minutes, confer workable properties on the metal.

Aluminum Brass. This alloy contains 1 to 6 per cent aluminum, 24 to 42 per cent zinc, and 55 to 71 per cent copper. It is used for bushings and hardware, and in cases where an accurate-sized casting is required. Aluminum brasses, whose percentage of aluminum exceeds 4 per cent, cannot be worked easily. The tensile strength of aluminum brass is about 85,000 pounds per square inch; yield strength about 73,000 pounds per square inch; per

cent elongation, 6; and per cent reduction in area, 8; Brinell hardness number 193.

Aluminum Bronze. This is one of a number of alloys in which aluminum is alloyed in small percentages with another metal which forms the base. It contains from 5 to 11 per cent of aluminum, the remainder being copper, and is a very dense, fine-grained and strong alloy. With 10 per cent of aluminum, forged bars will have a tensile strength of 100,000 pounds per square inch and an elastic limit of 60,000 pounds per square inch, with an elongation of 10 per cent in 8 inches, and a specific gravity of about 7.5. If from 5 to 7.5 per cent of aluminum is used, the specific gravity will be from 8 to 8.30, with a tensile strength of from 78,000 to 80,000 pounds per square inch, an elastic limit of 40,000 pounds per square inch, and an elongation of 30 per cent in 8 inches. Alloys containing 95 per cent of copper and 5 per cent of aluminum have a tensile strength of about 55,000 pounds per square inch and an elastic limit of about 25,000 pounds per square inch. The values for tensile strength given above for aluminum bronzes are based upon tests with specially high-grade material made from very pure metals and cannot be expected to be obtained in all cases in the commercial brass foundry. It is safe to say, however, that aluminum bronzes will have a tensile strength of from 40,000 to 60,000 pounds per square inch with an elongation of from 10 to 20 per cent in 8 inches. Aluminum bronze can be drawn into wire which is used for electrical resistance coils. The alloy withstands intense heat for an unlimited time without injury. If more than 11 per cent of aluminum is added to copper, the alloy is too brittle to be of any commercial value. With an aluminum content of about 9 or 10 per cent, the best all-around results are obtained.

Aluminum Bronze, Cast. This alloy has considerable strength, resistance to corrosion, hardness equal to manganese bronze, and good bearing qualities under certain conditions. The S.A.E. Standard No. 68 is used for worm-wheels, gears, valve guides, valve seats, and forgings.

Composition of No. 68: Copper, (Grade A) 87 to 89, (Grade B) 89.50 to 90.50; aluminum, (Grade A) 7 to 9, (Grade B) 9.50 to 10.50; iron, (Grade A) 2.50 to 4, (Grade B) not over 1; tin, max., (Grade A) 0.5, (Grade B) 0.2; total other impurities, (Grade A) 1, (Grade B) 0.5 per cent.

Physical Properties: Tensile strength, (Grades A and B) as cast, 65,000 pounds per square inch; tensile strength, (Grade B) as heat-treated, quenched and drawn, 80,000 pounds per square inch; yield point, (Grades A and B) as cast, 25,000 pounds per square inch; yield point, (Grade B) as heat-treated, 50,000 pounds per square inch.

Aluminum Bronze, Wrought. This alloy has great strength, high resistance to corrosion, and a hardness equal to manganese bronze. It has good bearing and anti-friction properties and is used for gears, forgings, hot-forged valve seats and bushings for internal-combustion engines. The 10 per cent alloy can be heat-treated in a manner similar to steel. The physical properties improve somewhat by heating and quenching.

Composition of S.A.E. Standard No. 701: Copper, 88 to 95; aluminum, 4.5 to 10; iron, max., 4; other additions including nickel, tin and manganese, max., 2; other impurities including zinc and lead, max., 0.25 per cent.

Physical Properties: The ultimate strength (pounds per square inch) of rods and bars varies from 72,000 to 80,000; and plates, sheets and strips, from 50,000 to 60,000. The yield point of rods and bars (pounds per square inch) varies from 30,000 to 40,000; and plates, sheets and strips, from 20,000 to 24,000. This material must withstand cold bending without fracture through an angle of 120 degrees around a pin, the radius of which is equal to the diameter or thickness of the material.

Aluminum Die-Casting Alloy. See Die-casting Alloy, Aluminum-base.

Aluminum, Gun-Metal Finish. See Gun-metal Finish on Aluminum.

Aluminum-Monel. When a small percentage of aluminum is added to Monel metal, the alloy becomes non-magnetic. This alloy possesses great strength. Used for airplane parts located close to the compass, and for struts and guide wires on airplanes.

Aluminum Oxide. Artificial abrasives of the aluminum oxide class are produced in electric furnaces from bauxite, which is a soft earth, and is the purest form of aluminum oxide found in nature. The oxide crystallizes when bauxite is fused in the electric arc furnace, and because of the abrasive being artificially produced, undesirable elements can be eliminated. It is due to this fact that artificial abrasive wheels have become popular. Crystalline aluminum oxide ranges in color from white to deep wine color. Wheels made from this abrasive are recommended for grinding materials having a high tensile strength, including the various steels, annealed malleable iron, wrought iron, tough bronzes and tungsten. Aluminum oxide grains are hard, tough, and dense, and when fractured, leave sharp cutting edges. The aluminum oxide abrasives have various trade names such as "Adamite," "Alowalt," "Aloxite," "Alundum," "Alu-lion," "Aluminox," "Bikorund," "Borite," "Boro-Carbone," "Borolon," "Coralox," "Corowalt," "Corundite," "Electrit," "Electrorubin," "Lionite," "Natite," "Staralox," "Sterlith," "Veral."

Aluminum Paint. Aluminum paint is opaque to sunlight and possesses high heat and light reflecting qualities. The high light reflectivity makes the paint particularly satisfactory for painting dark buildings, rooms, mills, etc. High reflectivity also means low absorption; therefore, when a tank or other chamber should be kept cool inside, this is facilitated by painting the outside with aluminum paint. It is the reason that an increasing number of gas and oil storage tanks and oil-tank cars are being painted with aluminum paint. In investigations conducted on oil storage tanks in the southwest, by the United States Bureau of Standards, it was found that the temperature of oil in tanks coated with aluminum paint was several degrees lower than in tanks coated with other paints. Furthermore, due to the lower temperature, there is a much smaller loss of the highly volatile oils from tanks coated with aluminum paint. It is evident from the foregoing that aluminum paint should not be used on radiators.

Aluminum Soldering. Some fractured and defective aluminum alloy castings can be repaired quite satisfactorily by the oxy-acetylene process, but often it is undesirable to heat the parts to the relatively high temperature necessary for welding, because of the resulting distortion. In such cases, a means of joining the parts without heating them to a high temperature is desirable. Aluminum parts can be permanently repaired by soldering when the solder can be made to adhere to the aluminum and when the joint thus made is not subject to deterioration. Aluminum cannot be soldered by the same process as that which the tinsmith uses in soldering tin and copper with a hot copper bit and a solder that will flow and follow the copper. The practice with aluminum is more like brazing with hard solders.

A solder joint in aluminum, on exposure to moisture, will not remain permanent, as galvanic cells are set up which cause the joint to become rapidly disintegrated by auto-corrosion. One of the most severe tests to which a solder joint can be subjected is that of placing it in steam; hence solder joints should be protected against corrosion by a bitumastic paint or varnish.

Aluminum Solder: A suitable solder for joining aluminum may be composed solely of tin and zinc, the amount of zinc employed ranging, perhaps, from 15 to 50 per cent. Another solder for aluminum consists of a mixture of tin, zinc, and aluminum. In this mixture, the amount of zinc may vary from 8 to 15 per cent, and the aluminum from 5 to 12 per cent. The tensile strength of a good aluminum solder is about 7000 pounds per square inch. It is desirable that the solder should not be brittle and it is best applied without a flux.

The process of tinning is accomplished by heating the surfaces to be joined with an atmospheric gas torch or a kerosene blowtorch, to a temperature somewhat above the fusing point of the solder, and then rubbing the surface with the point of a tinned steel tool which serves to remove the outside film and allows the solder to act upon the clean surface. The higher the temperature —within certain limits—at which the tinning is done, the better will be the adhesion of the tinned layer. After the surfaces to be joined have been properly tinned, they are joined by pressing them together and again heating to the required temperature, as determined by the composition of the solder. If necessary, the joint may be smoothed with a spatula just before the solder hardens, care being taken not to move the work until the solder has become thoroughly set.

Aluminum Welding. The successful welding of aluminum alloy castings by the oxy-acetylene process, depends a great deal upon the success achieved in breaking down the aluminum oxide, the forming of which is intensified as soon as the oxy-acetylene torch flame comes in contact with the metal. It is this oxide film that prevents the proper flow of the metal at the welding temperatures and that has been the cause of many failures in aluminum welds.

Cleaning Surfaces: The surfaces to be joined must be thoroughly cleaned and the material near the surfaces to be welded must also be clean, as otherwise the impurities near the joint will invariably set up auto-corrosion in the weld. Oily machine parts should be allowed to remain for a few seconds in a hot 10 per cent caustic soda solution, after which, the castings should be thoroughly washed and scrubbed in plenty of clean hot water. It is often advisable first to wash the oily castings with gasoline to remove the greater part of the grease and dirt.

Joint Beveling: After the work is cleaned, a V-shaped groove is filed or chipped along the crack or seam to the bottom to permit the metal to be melted the full depth of the work. However, aluminum alloy castings up to ¼ inch in thickness can be welded with the torch flame without beveling the joints.

Preheating: In welding aluminum and aluminum alloy castings, it is necessary to preheat and anneal the work in order to prevent too rapid expansion and contraction of the metal. Preheating also conserves gas, increases the rate of welding, and prevents warping. Great care, however, must be exercised to avoid exceeding a temperature of 750 and 840 degrees F., respectively, when preheating and reheating or annealing the work. At higher temperatures a piece of work may be rendered useless by deformation. During the preheating of castings of complex

shape or castings that vary greatly in thickness, the casting should be covered with sheet asbestos to keep the temperature as uniform as possible. The asbestos should not be removed during the welding operation, except as it is necessary to effect the weld.

Welding Procedure: A puddling rod, made from a piece of mild steel rod 3/16 or ¼ inch in diameter and flattened on one end like a flat scraper, is used in welding to scrape and agitate the metal at the moment of melting in order to break up the oxide and allow the molten metal to flow together. It is necessary to wipe the puddling rod frequently to prevent it from becoming coated with oxide, and care must be taken not to allow it to reach a red heat, as otherwise oxide of iron will be formed on it which might result in a defective weld. The oxide formed in the course of melting aluminum offers considerable resistance to the welding flame, and it must be eliminated to effect a homogeneous weld. This is best done by employing an aluminum alloy welding flux which dissolves and deoxidizes the layer of oxide adjacent to the joint to be welded, at the temperature at which the aluminum reaches a molten state.

The welding material, usually a rod or broken aluminum part, should be of as pure aluminum as it is possible to obtain and the end of the rod should be kept in the molten bath while welding. For aluminum alloy castings, the welding material should be of approximately the same composition as the alloy to be welded.

Flame Adjustment: In making a weld, the torch flame should be so adjusted that it will furnish a slight excess of acetylene, and it is essential to avoid contact of the white-hot bulb of cone with the metal that is about to become molten, because the hot temperature in this part of the flame tends to produce holes in the metal which are often difficult to repair. The correct distance varies according to the size of torch tip employed, but in general, the distance should be from ¼ to ¾ inch. After welding, the casting should be reheated evenly and allowed to cool very slowly. When the casting is cold, it should be thoroughly washed in hot water to remove all traces of the flux, which would otherwise continue to produce a chemical action on the metal that would result in harmful corrosion.

Aluminum Welding Fluxes. The oxide formed in the course of melting aluminum offers considerable resistance to the welding flame. It does not always rise to the surface, especially if the work is thick, yet it must be eliminated to effect a homogeneous weld. This is done by employing a flux which dissolves and deoxidizes the layer of oxide adjacent to the joint to be

welded, at the temperature at which the aluminum reaches a molten state. Another function of a flux is to protect the fused metal from contact with the air.

An example of a good flux for aluminum and aluminum alloys with a melting point of approximately 1110 degrees F. is one containing a mixture of lithium chloride, potassium chloride, potassium bisulphate, and potassium fluoride. The reactions that take place in the application of such a flux are believed to be as follows: The potassium fluoride reacts with the potassium hydrogen sulphate, forming hydrofluoric acid, and this immediately acts on the aluminum oxide, forming aluminum fluoride, which is free to combine with the excess of potassium fluoride existing in the flux, forming potassium aluminum fluoride, which is capable of dissolving a further quantity of aluminum oxide. The lithium chloride and potassium chloride serve the purpose of lowering the fusion point of the mixture.

When castings that have sand on their surface are to be welded, a flux that will remove the sand must be used. If the sand is not removed, it is in part reduced, resulting in silicon being passed into the metal — a condition that often reduces the strength of the weld an appreciable amount. A flux that is adapted for use under these conditions is composed of potassium chloride or fluorspar. This flux will prevent silicon from entering the alloy.

The flux may be applied in paste form to the surfaces to be welded, or the parts may be heated and the powdered flux sprinkled over the joint, or the end of the welding rod may be heated and dipped into the flux, which readily adheres to it in the form of a thin varnish; the last method is the safest and best. The powdered fluxes should be kept free from dust and dirt, and preferably in air-tight containers, as they absorb moisture rapidly.

Alundum. "Alundum" is the registered Norton Company trade-mark designating all brands of aluminum oxide abrasive as well as all refractory and laboratory ware, and other products derived from these materials. In general, Alundum abrasive is used for grinding materials of high tensile strength—materials that are hard, yet tough and strong.

Amalgams. Alloys formed by mercury and other metals are known as "amalgams." Many of these are formed by direct contact of a metal with mercury; others are formed when the metal and mercury are placed together in dilute acid. In still other cases, mercury is added to the solution of a metallic salt,

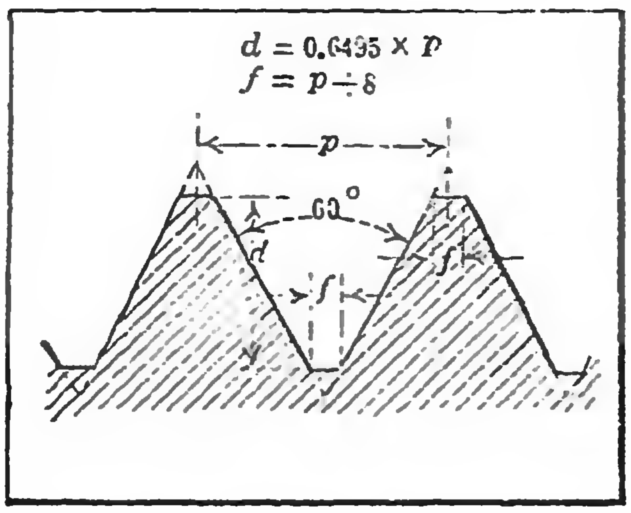
or the metal is added to the solution of mercury nitrate. When newly made, amalgams are plastic, but they harden after a short time and then usually either expand or contract to a considerable extent. The most common metals that combine with mercury to form amalgams useful in the industries are tin, copper, cadmium, bismuth, silver, and gold. Tin amalgam is used for silvering mirrors. Copper and cadmium amalgams are used in dentistry, silver and gold amalgams are used in silvering and gilding, and an amalgam of zinc and tin is used in electrical machinery. Zinc plates of electric batteries are covered with an amalgam in order to reduce the polarization. Many amalgams are useful as cements for metals, the cement being applied in its plastic form when newly made, and hardening after a short interval, as mentioned.

American Standard Screw Thread System. The American Standard screw thread is a development of the older U. S. Standard which it has superseded. The American Standard is the same as the U. S. Standard so far as thread form or profile is concerned. The number of threads per inch for a given diameter is also the same, with the exception of diameters above 2¾ inches. According to the American Standard, screw threads from 2½ to 4 inches, inclusive, all have 4 threads per inch. According to the older U. S. Standard, the 3- and 3¼-inch diameters have 3½ threads per inch; the 3½-inch diameter, 3¼ threads per inch; and the 3¾- and 4-inch diameters, 3 threads per inch. The present American Standard does not extend beyond the 4-inch diameter. The U. S. Standard includes diameters up to 6 inches.

Series of Pitches: The American Standard has five series of pitches known as the Coarse-thread Series, the Fine-thread Series, the 8-Pitch, 12-Pitch and 16-Pitch Series. In the Coarse- and Fine-thread series, the numbers of threads per inch decrease as the diameters increase. In the 8-Pitch Series, all diameters included have 8 threads per inch; similarly, all diameters in the 12-Pitch Series have 12 threads per inch, and, in the 16-Pitch Series, 16 threads per inch. The Coarse-thread and Fine-thread series (especially the former) are intended for general application, whereas the 8-pitch, 12-pitch and 16-pitch series are more special. For example, the 8-pitch series is intended for such parts as cylinder head studs, bolts for high-pressure pipe flanges, or similar fastenings requiring an initial tension and a pitch that remains the same for all diameters. The 12-pitch series is used in boiler practice and also in machine construction for thin nuts on shafts and sleeves. The 16-pitch series is intended mostly for threaded adjusting collars, bearing retaining nuts, or any other applications requiring a fine thread.

Symbols Used in Specifying American Standard: If the drawing calls for a 1½-inch American Standard thread, 6 threads per inch, this standard and size may be indicated merely by the use of a symbol or abbreviation as follows: 1½-6 NC. This is an American Standard symbol. The diameter is given first, then the number of threads per inch. The letters "NC" represent National Coarse-thread Series. The American Standard also includes a Fine-thread Series, and for this symbol would be changed as follows: 1½-12 NF. In this case, the "NF" means the National Fine-thread Series. The American Standard also includes tolerances and allowances for four different classes of fits designated by numbers. The symbol 1½-6 NC-2 means that the screw thread is to have a Class 2 fit, the fit number following the symbol indicating the diameter and number of threads per inch.

Advantages of American Standard Form: The American Standard form has largely replaced the sharp V-thread, because of its superiority. As the American Standard has a flat top (see illustration), it is not so easily injured as a sharp V-thread, and taps and dies wear less at the points of the teeth and retain their size longer. Screws having American Standard threads are from one-eighth to one-fourth stronger to resist tension than screws with V-threads, because, for a given outside diameter, there is a larger root diameter or effective area. For instance, an American Standard screw thread of 1 inch outside diameter and eight threads per inch has a root diameter of 0.8376 inch, whereas a screw of corresponding outside diameter and pitch, but with a sharp V-thread, has a root diameter of 0.7835 inch. The relative strength varies according to the size of the screw, the smaller American Standard screws being approximately one-fourth stronger than those having V-threads, whereas the larger sizes are only about one-eighth stronger in tension.



American Standard Thread

The sides of the American Standard thread form an angle of 60 degrees with each other in the plane of the axis of the screw. The width of the flat at the top and bottom equals one-eighth of the pitch. If $p =$ pitch of thread, $d =$ depth of thread, and $f =$ width of flat at top and bottom of thread, then:

$$p = \frac{1}{\text{number of threads per inch}}$$

$$d = \tfrac{3}{4} \times p \times \cos 30 \text{ deg.} = 0.649519\, p = \frac{0.649519}{\text{No. of threads per inch}}$$

$$f = \frac{p}{8} = \frac{1}{8 \times \text{number of threads per inch}}$$

American Standard Taper Pipe Thread. The angle between the sides of the thread is 60 degrees when measured in an axial plane, and the line bisecting this angle is perpendicular to the axis. The crest and root of thread are truncated a minimum amount equal to 0.033 $\times$ pitch except for 8 threads per inch which (according to 1942 revision) are truncated 0.045 $\times$ pitch at the crest and 0.033 $\times$ pitch at the root. The (basic) maximum depth of the truncated thread is 0.80 $\times$ pitch except for 8 threads per inch which is 0.788 $\times$ pitch. The taper of the thread is 1 in 16 or 0,75 inch per foot, measured on the diameter and along the axis. If E = pitch diameter at the end of the taper thread, D = outside diameter of pipe, and E = pitch diameter at small end of thread, then

$$E = D - (0.050\, D + 1.1) \times \text{pitch}$$

The standard shows flat surfaces at crest and root, but rounded surfaces of commercially manufactured threads will be acceptable if the rounding is within certain tolerance zones.

American Steel and Wire Co.'s Gage. The Bureau of Standards at Washington recommends that this be referred to as Steel Wire Gage, which see.

American Wire Gage. This gage is used for bare and insulated wire of aluminum and copper; for all bare wire made of brass, phosphor-bronze, German silver, or zinc; for resistance wire of German silver or other alloys; for rods of brass, copper, and aluminum; for sheets of brass, phosphor-bronze, aluminum, and German silver. The American Wire Gage is also known as the Brown & Sharpe.

Ammeter. An ammeter or ampere-meter is an instrument for measuring the rate of flow of electric current in amperes. Several different forms of this device have been constructed, the fundamental types of which are the Weston meter, the Thomson meter, the electrodynamic meter and the electrothermic meter.

In the *Weston meter* a stationary permanent magnet acts upon a movable wire coil which is shunted by a low resistance. This meter is used for direct current only.

The *Thomson meter* consists of a small movable piece of soft iron which is acted upon by an inclined stationary wire coil through which the current to be measured passes.

The *electrodynamic meter* consists of a movable and a stationary wire coil acting magnetically upon one another. .The coils

are connected in series, the movable coil carrying the indicating needle.

There are two types of *electrothermic meters*, the hot-wire type and the thermocouple type. In the hot-wire meter, the current passes through a straight wire, and the amperage is measured by the expansion of the wire caused by the heating effect of the current. The expansion is transmitted by a lever to an indicating needle. The thermocouple type of meter has largely superseded the hot-wire type due to lower power loss and much greater sensitivity. In this type, suitable for use in measuring alternating currents of all frequencies, a series of junctions of two different metals is used which, when heated by the current being measured, produce a direct current to actuate a direct current measuring mechanism.

Suitable scales are provided in all types so that the current values may be read off directly in amperes, milliamperes or micro-amperes.

Amortisseur Winding. In electrical machinery, an amortisseur winding is used for making synchronous motors self-starting and for preventing hunting of synchronous generators, caused by an irregularity in the operation of the prime mover. The winding is generally of the squirrel-cage type and consists of metal rings or ring sections into which are welded or riveted bars of copper, bronze, or some other alloy of different resistance. The bars are imbedded in the pole faces of the machine, as near to the surface as practicable and parallel to the armature slots, and are usually arranged in individually short-circuited groups with bolted or otherwise separable connections between groups. This constitutes a permanently short-circuited winding so arranged as to oppose rotation or pulsation of the magnetic field with respect to the pole shoes.

Ampere. The unit of the rate of flow of an electric current, known as the *ampere*, is one-tenth of the unit of current in the centimeter-gram-second system of electro-magnetic units. It is the practical equivalent of a current which, when passed through a solution of nitrate of silver in water, deposits silver at the rate of 0.001118 gram per second. The current of an ampere will be produced by an electromotive force of one volt applied to a conductor, the resistance of which is one ohm. An ampere is also equal to the flow of a quantity of electricity of one coulomb per second. The current in amperes is measured by *ampere-meters*, also known as *ammeters*.

Ampere-Hour. The quantity of electricity corresponding to one ampere flowing for one hour; it is equal to 3600 coulombs.

Ampere-Hour Meters. Ampere-hour meters are of two general types, the *electrolytic* and the *motor-types.* Their use is now confined practically to direct-current circuits, chiefly in connection with storage batteries or other electrolytic applications. Abroad, they have been used to some extent in the place of watt-hour meters, by assuming a fixed supply voltage. Ampere-hour meters of the electrolytic type operate on the principle of the *voltameter,* the weight or volume of the products of chemical decomposition being proportional to the ampere-hours. Motor-type ampere-hour meters are of the *commutator* and the *mercury-motor types.* In the former, a permanent magnet furnishes the field in which rotates an armature carrying a small current diverted from a shunt in the main circuit. In mercury ampere-hour meters, a rotor (usually a copper disk but sometimes a cup), is submerged in mercury contained in a chamber. Current terminals are so introduced into the chamber that the current is led through the rotor, entering and leaving by way of the mercury which serves as a contact maker. The rotor is placed in the field of a permanent magnet, rotation resulting from the interaction of the current in the rotor with the magnetic field. By the use of shunts, the meter is adapted to measure larger currents than can be handled directly.

Ampere-Second. The quantity of electricity corresponding to one ampere flowing for one second. It is equal to one *coulomb.*

Ampere-Turn. The unit of magnetomotive force. The number of ampere-turns of a circuit equals the product of the number of amperes flowing in the circuit multiplied by the number of turns, usually in the form of a coil or coils, in the circuit.

Analysis, Magnetic-Mechanical. See Magnetic-mechanical Analysis.

Analytical Chemistry. That part of chemistry which deals with the methods for determining the components of a substance. Analytical chemistry determines not only the kinds of elements that may be present in a substance, but also the amount of each.

Analytical Geometry. That part of the science of mathematics in which the location of points, lines, and surfaces is expressed by means of equations, and in which the geometrical properties can therefore be investigated by means of algebraic operations, or algebraic expression be shown graphically by means of points or lines. In analytical geometry, the location of a point is given by stating its distance from two lines or axes which intersect each other in the case of plane analytical geometry, and from three axes intersecting at one point in the case of analytical geometry in three dimensions.

Anemometer. The anemometer is an instrument for measuring the velocity or pressure of the wind, and may also be used for measuring the velocity of air in pipes of large diameter. Experiments have shown, however, that anemometers are not reliable for the measurement of velocities of air in pipes, especially when the diameters do not exceed 24 inches, the instrument generally giving too low results when used in this manner. It has also been found that the percentage of error is not constant, but varies considerably with the diameter of the pipe and the speed of the air. Anemometers are divided into two main classes, those that measure the velocity and those that measure the pressure of the air or wind. There is, however, a close relationship between the pressure and the velocity, so that an instrument of either class can easily be made to give direct readings for both of these quantities.

Angle. When two lines intersect, an angle is formed between them. The point where the two lines intersect is called the *vertex* of the angle. Angles are measured in degrees, minutes, and seconds (1 degree = 60 minutes; 1 minute = 60 seconds). A 90-degree angle is known as a *right* angle. Angles larger than 90 degrees are called *obtuse* angles, and those less than 90 degrees, *acute* angles. The two lines forming an angle are called the *sides* of an angle. The sides of a 90-degree angle are *perpendicular* to each other.

Angle Diameter. The pitch diameter of a screw thread is sometimes called the "angle diameter," because it is measured in the angle of the thread either by using a special type of micrometer or by means of the well-known three-wire method. The pitch or angle diameter is the diameter measured halfway between the theoretical top and bottom of a screw thread, and, therefore, equals the theoretical outside diameter minus the thread depth. The term "pitch diameter" is recommended. The pitch diameter of a straight screw thread is the diameter of an imaginary cylinder the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces cut by the surface of the cylinder.

Angle of Advance. The angle of advance, or "angular advance," as it is sometimes called, is generally considered the angle through which the eccentric of a steam engine must be turned to move the valve from its mid-position to the position which it occupies at the beginning of the piston stroke. This movement of the valve on its seat equals the outside lap plus the lead; hence, the angle of advance equals the angle due to the outside lap plus the angle due to the lead. The total angle

between the crank and eccentric is sometimes referred to as the angle of advance. The definition first given, however, is generally considered correct, and is more convenient to use in connection with valve diagrams and the study of valve motions, in general.

Angle of Repose. If a body is placed on an inclined plane, the friction between the body and the plane will prevent it from sliding down the inclined surface, provided the angle of the plane with the horizontal is not too great. There will be a certain angle, however, at which the body will just barely be able to remain stationary, the frictional resistance being very nearly overcome by the tendency of the body to slide down. This angle is termed the *angle of repose* and the tangent of this angle equals the coefficient of friction. The angle of repose is frequently denoted by the Greek letter. θ. Thus, $\mu = \tan \theta$. A greater force is required to start a body from a state of rest than to merely keep it in motion, because the *friction of rest* is greater than the *friction of motion.*

Angle Plate. A cast iron or forged piece having two surfaces at an angle to each other, usually a right angle, and used for holding work to be machined. One face is clamped to the machine face-plate or table and the work is supported by the other face.

Angles, Functions. See Functions of Angles.

Angle Shears. What are known as *angle shears* are designed especially for cutting angle iron and similar shapes. A common form of machine has two cutter-slides which move downward at an angle of 45 degrees with the work table.

Angle, Structural. This is one of the common standard structural sections. See Structural Shapes.

Angular Velocity. The angular velocity of a rotating body is expressed in angular measure and equals the angle through which any radius of the body turns in one second. This angle is generally expressed in radians.

$$\text{One radian} = \frac{180}{\pi} = \frac{180}{3.1416} = 57.3 \text{ degrees.}$$

The angular velocity in radians is generally denoted by the Greek letter ω. If r = radius of revolving body in feet; n = number of revolutions per minute; and v = velocity of a point on the periphery, in feet per second; then,

$$v = \frac{2\,\pi r n}{60}; \quad \omega = \frac{v}{r} = \frac{2\,\pi n}{60}; \quad v = \omega r.$$

Anhydrid. An oxide which unites with water to form an acid. Generally these oxides are non-metallic, although sometimes metallic oxides are anhydrid.

Animal Glue. See Glues for Wood.

Annealing. Annealing involves reheating and cooling of metals which are in the solid state. Annealing usually implies relatively slow cooling as compared, for example, with normalizing, and the purpose of annealing may be either (1) to remove stresses, (2) to soften a metal as for machining, (3) to change the ductility, toughness, electrical, magnetic or other physical properties; or (4) to refine the crystalline structure. The annealing temperature and rate of cooling depend upon the material and purpose of the treatment.

A common method of annealing steel is to pack it in a cast-iron box containing some material, such as powdered charcoal, charred bone, charred leather, slacked lime, sand, fireclay, etc. The box and its contents are then heated in a furnace to the proper temperature, for a length of time depending upon the size of the steel. After heating, the box and its contents should be allowed to cool at a rate slow enough to prevent any hardening. It is essential, when annealing, to exclude the air as completely as possible while the steel is hot, to prevent the outside of the steel from becoming oxidized.

The temperature required for annealing should be slightly above the critical point, which varies for different steels. Low-carbon steel should be annealed at about 1650 degrees F., and high-carbon steel at between 1400 and 1500 degrees F. This temperature should be maintained just long enough to heat the entire piece evenly throughout. Care should be taken not to heat the steel much above the decalescence or hardening point. When steel is heated above this temperature, the grain assumes a definite size for that particular temperature, the coarseness increasing with an increase of temperature. Moreover, if steel that has been heated above the critical point is cooled slowly, the coarseness of the grain corresponds to the coarseness at the maximum temperature; hence, the grain of annealed steel is coarser, the higher the temperature to which it is heated above the critical point. If only a small piece of steel or a single tool is to be annealed, this can be done by building up a firebrick box in an ordinary blacksmith's fire, placing the tool in it, covering over the top, then heating the whole, covering with coke and leaving it to cool over night. Another method is to heat the steel to a red heat, bury it in dry sand, sawdust, lime, or hot ashes, and allow it to cool.

Annealing Aluminum. See Aluminum Annealing.

Annealing Chains. See Chain Annealing.

Annealing High-Speed Steel. Experiments to determine the temperature to which high-speed steel should be heated for annealing, indicated that when this steel was heated to below 1250 degrees F. and slowly cooled, as in annealing, it retained the original hardness and brittleness imparted to the steel in forging. When heated to between 1250 and 1450 degrees F., the Brinell test indicated that the steel was soft, but impact tests proved that the steel still retained its original brittleness. However, when heated to between 1475 and 1525 degrees F., the steel became very soft, it had a beautiful fine-grained fracture, and all of the initial brittleness had entirely disappeared. In carrying these tests further, to 1600, 1750, and 1850 degrees F., it was found that the steel became very soft, but there was a gradual increase in brittleness and in the size of the grain, until at 1850 degrees F. the steel became again as brittle as unannealed steel; the fracture at this temperature was dull, dry, and lifeless, and showed marked decarbonization. Dried air-slacked lime was used as a packing medium in making these tests. The steel was packed in tubes both ends of which were afterward provided with air-tight caps. The decarbonization that took place was probably due to the oxygen in the air that had filled the intervening spaces between each minute particle of lime, before it was packed in the tube, attacking the carbon of the steel; this decarbonization would not have taken place if powdered charcoal had been used. The latter would have supplied all the carbon necessary to combine with any oxygen present in the tubes.

Annealing Malleable Iron Castings. Annealing of malleable iron castings is heat-treatment designed to produce tough and ductile malleable iron from hard castings. This change is brought about by changing the pearlite and cementite of the iron to ferrite and temper carbon, which is done by heating the castings up to the temperature at which the cementite breaks down into iron and carbon. For furnace malleable castings, the temperature is maintained from 1450 degrees F. to a maximum temperature of 1600 and in some cases 1650 degrees F.

Malleable iron usually has a white outer band, approximately 1/64 inch thick, followed by a dark gray band and a velvety black interior. As the annealing proceeds, the steel band around the casting becomes thicker and the gray band thinner.

Annealing, Water Method. Quick annealing can be partially effected by what is known as "water annealing." The steel is slowly heated to a cherry red, and is then removed from the furnace. A piece of soft wood is used to test the heat of the piece of steel as it is decreasing, the heat being tested by touching the

steel with the end of the stick. When the piece of steel has cooled so that the wood ceases to char, the steel is plunged quickly into soapy water. Very often a piece of steel annealed in this manner will be found to be much softer than if annealed in the regular way by being packed in charcoal and allowed to cool over night.

Anode. The electrodes by means of which current enters and leaves any conductor of the non-metallic class, such as an electrolyte, are known as *anode* and *cathode*, respectively. An anode is an electrode through which current enters any conductor of the non-metallic class. Specifically an electrolytic anode is an electrode at which negative ions are electrically discharged, or positive ions are formed, or at which other oxidizing reactions occur. According to the convention that an electric current travels from positive to negative polarity, it follows that the anode of an electroplating bath is connected to the positive terminal of the generating source, and the cathode to the negative.

Anodizing. A process which results in the anodic oxidation of non-ferrous metals usually for the purpose of protecting the base metal from corrosion and abrasion.

Anthracite Coal. The different kinds of coal all contain carbon, hydrogen, oxygen, and nitrogen, forming a carbonaceous or combustible portion, and also some matter which remains after the combustion in the form of ash. The amount of ash varies considerably in different kinds of coal. *Anthracite* coal contains over 90 and sometimes up to 97 per cent of carbon and has a heating value per pound of combustible of from 14,500 to 15,000 B.T.U. Anthracite is slow to ignite, and burns slowly. It is classified, according to the sizes of the pieces or lumps of the coal as obtained from the mine, into ten different kinds, ranging from "lump" to "culm." The various kinds are as follows: Lump coal, which does not pass through bars set from 3½ to 5 inches apart; steamboat coal, which does not pass through 3½-inch mesh; broken coal, which does not pass through 2¾-inch mesh, but passes 3½-inch mesh; egg coal, which does not pass 2-inch mesh, but passes 2¾-inch mesh; stove coal, which does not pass 1⅜-inch mesh, but passes 2-inch mesh; chestnut coal, which does not pass ¾-inch mesh, but passes 1⅜-inch mesh; pea coal, which does not pass ½-inch mesh, but passes ¾-inch mesh; buckwheat, which does not pass through ⅜-inch mesh, but passes ½-inch mesh; rice coal, which does not pass 3/16-inch mesh, but passes ⅜-inch mesh; culm or slack of screenings, which passes through 3/16-inch mesh. For power plants, pea, buckwheat, rice, and culm coal are generally used, the price of these sizes being considerably less than that of the larger sizes. *Semi-anthracite* coal is similar to anthracite. It contains from 85 to 90 per cent of

carbon and has a heating value, per pound of combustible, of from 14,500 to 15,500 B.T.U. It is not as hard as regular anthracite, is less shiny, and burns more rapidly.

Anti-Fatigue Steel. This term is sometimes applied to vanadium steel because of its unusual resistance to continued shocks and vibrating stresses. (See Vanadium Steel.)

Anti-Freezing Mixtures. Anti-freezing mixtures for use in the radiators of gasoline engines are used to lower the freezing point below the lowest atmospheric temperature liable to occur during cold-weather operation. Alcohol and water mixtures have been widely used. Either denatured or wood alcohol may be used. The following figures represent percentages by volume of alcohol in the water and the corresponding freezing temperatures.

Denatured Alcohol: 20 per cent added to cooling water—freezing temperature, +19 degrees F.; 30 per cent, +10 degrees F.; 40 per cent, —2 degrees F. below zero; 50 per cent, —18 degrees F. below zero.

Wood Alcohol: 20 per cent added to cooling water—freezing temperature, +10 degrees F.; 30 per cent, —2 degrees F. below zero; 40 per cent, —20 degrees F. below zero; 50 per cent, —40 degrees F. below zero.

Wood alcohol should not be used unless it is definitely known to be free from acetic acid. Owing to the fact that alcohol evaporates much faster than water, the specific gravity of the mixture should be tested occasionally with a hydrometer calibrated for temperature correction. Alcohol lowers the boiling point of water, so that abnormal evaporation may occur, especially on a warm day.

Glycerine Mixtures: Glycerine raises the boiling point of water and does not evaporate like alcohol, but it is said to be somewhat more injurious to any rubber connections used between the radiator and engine. The freezing temperatures of distilled glycerine and water mixtures are as follows: 20 per cent glycerine (by volume) added to cooling water—freezing temperature, +21 degrees F.; 30 per cent, +12 degrees F.; 40 per cent, zero; 50 per cent, —15 degrees F. below zero.

Ethylene Glycol: Ethylene glycol, like glycerine, does not evaporate so that the only replacement necessary is to compensate for leaks or mechanical losses. The freezing temperatures are as follows: 20 per cent ethylene glycol (by volume) added to cooling water—freezing temperature, +16 degrees F.; 30 per cent, +3 degrees F.; 40 per cent, —11 degrees F. below zero; 50 per cent, —31 degrees F. below zero.

Saline Solutions: Non-volatile anti-freezing mixtures may be made by dissolving either calcium chloride or magnesium chloride

in water. These solutions are less expensive than the alcohol and glycerine solutions, but they are considered inferior due to their tendency to attack metallic parts of the system, especially if there is any solder or aluminum. Two pounds of calcium chloride to 1 gallon of water may be used for temperatures down to 18 degrees F.; 3 pounds per gallon for temperatures down to 1 degree F.; 4 pounds for temperatures down to 17 degrees F. below zero; 5 pounds for temperatures down to 39 degrees F. below zero.

Anti-Friction Bearings. These are bearings which provide rolling contact and usually consist of two hardened steel rings or raceways between which one or more sets of hardened steel balls or rollers is located. An additional element known as a cage or separator serves to keep the rolling members at the proper distance from each other. In some designs, either of the two raceways may be omitted and the rolling members are then in direct contact with a hardened surface on the shaft or in the bearing housing. In others, a cage or separator is not employed and the rolling members are then in contact with each other.

Rolling contact bearings are manufactured to high standards of accuracy and to close material specifications both as to composition and heat treatment. The high degree of finish on rolling element and race is one result of the accuracy in manufacture required to prevent premature failure due to fatigue. Such fatigue, resulting from alternating stresses imposed upon the rolling members and the raceways, is the normal cause of ultimate failure and provides the basis for evaluating expected service life. A common indication of failure due to fatigue is pitting or flaking of the surfaces of the rolling members of raceways.

Anti-Friction Curve. Same as Tractrix.

Antimony. Antimony is a silver-white, crystalline, brittle metal of high luster; it is generally found in the mineral *stibnite*, from which it is obtained by first melting this mineral to free it from various foreign matter, and then roasting it to convert it into an oxide. After oxidation, this product is reduced by heating with carbon, metallic antimony thus being obtained. During this heating, loss through volatilization must be prevented by covering the heated mass with a protective layer of potash, soda, or glauber salt. Antimony is permanent in the air at ordinary temperatures but combines with oxygen when heated to a sufficient heat. It readily combines with many other metals, forming alloys that are used to a great extent in the industries. One of the most well-known of these is *type-metal*, which is an alloy of lead,

antimony, and tin, sometimes containing small percentages of copper and zinc. Antimony in alloys tends to give them hardness, and the property of expanding on solidification. This property is valuable in type casting, because it produces a letter that completely fills the molds.

The atomic weight of antimony is given by two investigators as 120 and 121, and is generally assumed to be 120.2; melting point, 630 degrees C. (1166 degrees F.); boiling point, 1440 degrees C. (2625 degrees F.), but the metal begins to vaporize at about 1300 degrees C. (about 2370 degrees F.); its specific gravity is generally given as 6.71, although it may vary from 6.70 to 6.86; assuming the specific gravity to be 6.71, the weight per cubic inch is 0.2422 and the weight per cubic foot, 418.7 pounds; specific heat, 0.0523; linear expansion per unit length per degree F., 0.00000627; electric conductivity (assuming that of silver to be 100), 3.59.

Antique Bronze Finish. See Bronzing.

Aperiodic. This term is sometimes applied to an electrical or other measuring instrument which is said to be "dead beat" or which has an indicating hand that moves to position without excessive oscillations. See Damping.

Apothecaries' Fluid Measure. 1 U. S. fluid ounce = 8 drachms = 1.805 cubic inches = 1/128 U. S. gallon; 1 fluid drachm = 60 minims; 1 British fluid ounce = 1.732 cubic inches.

Apothecaries' Weight. 1 pound = 12 ounces = 5760 grains; 1 ounce = 8 drachms = 480 grains; 1 drachm = 3 scruples = 60 grains; 1 scruple = 20 grains.

Apparent Density. A powder metallurgy term which denotes the weight of a unit volume of powder.

Apparent Power. The expression "apparent power" is used in connection with alternating-current circuits, to distinguish it from the true power or energy. It is the product of the mean effective value of the voltage across the circuit multiplied by the mean effective value of the current therein, as read directly from a voltmeter and ammeter. It is expressed in kilovolt-amperes (kva).

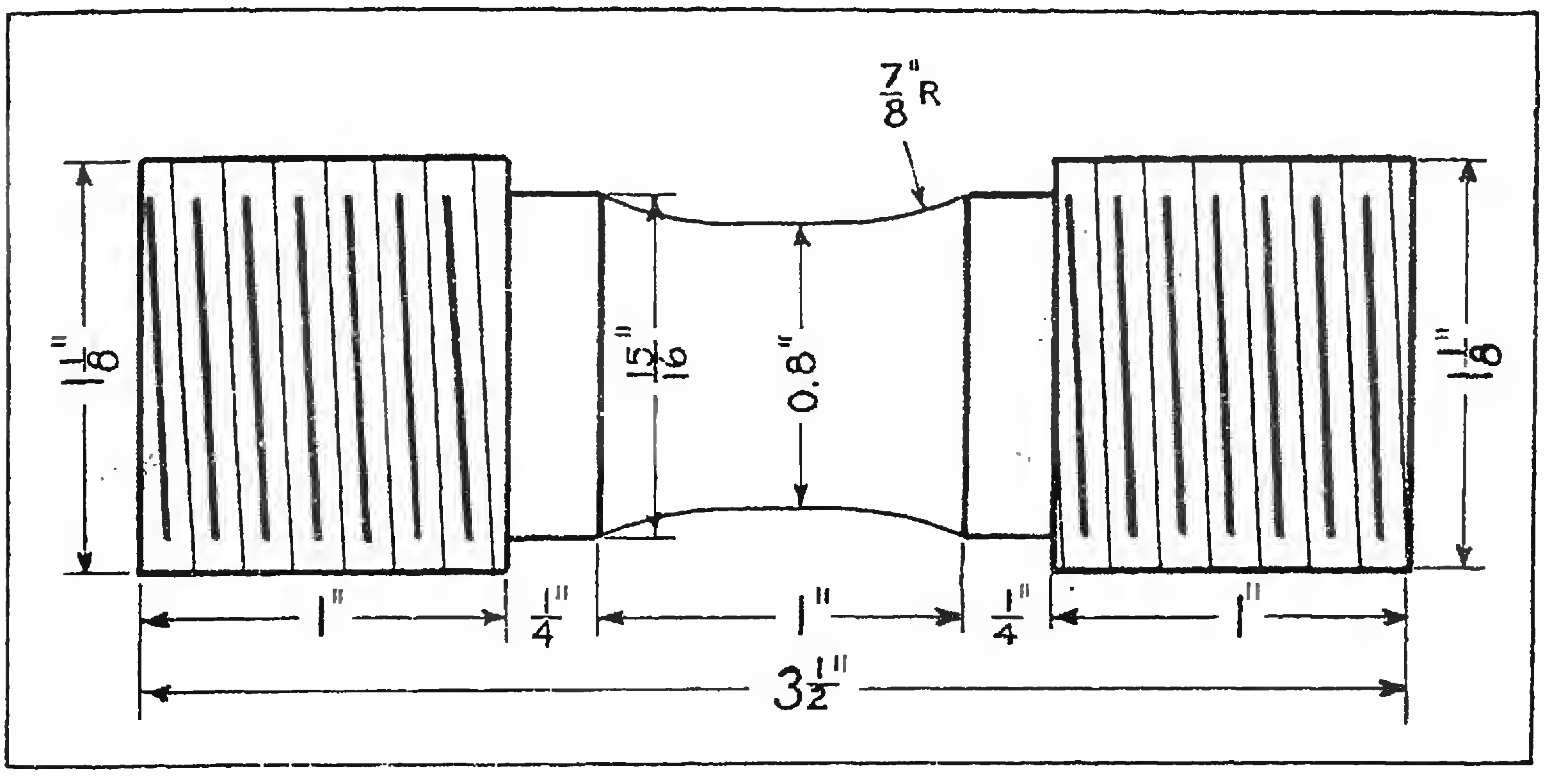
$$\text{Apparent power} = \frac{\text{true power}}{\text{power factor}}.$$

For unity power factor, the apparent power in volt-amperes is equal to the true power, expressed in watts.

Apron. In machine construction, a protecting cover which encloses a mechanism is sometimes called an apron, this term being applied particularly to the apron of a lathe which covers the mechanism employed for transmitting feed motion to the cross-slide and for engaging and disengaging the feed motion of either the cross-slide or the carriage.

Aqua-Fortis. A term applied especially to a weak grade of nitric acid.

Aqua Regia. Aqua regia is a mixture composed of three parts of hydrochloric (muriatic) acid and one part of nitric acid; it has a reddish yellow color, and has the peculiar quality of dissolving gold, platinum, and other rare metals which are insoluble in other acids. It is often used as an etching fluid, especially for



Standard Bar for Testing Tensile Strength of Cast Iron

high-speed steel. It should be used immediately after being prepared or mixed, as it loses its properties even after a short time.

Aquometer. An aquometer, more generally known as a *pulsometer*, may be defined as a steam pump which acts partly by direct steam pressure and partly by vacuum. See Pulsometer.

Arbitration Test Bar. This is the name of a test bar for cast iron conforming to the specifications of the American Society for Testing Materials. For transverse testing, the cast test bar has a body length of 21 inches and a diameter at the center of 1.2 inches. The diameter of the bar at the bottom is 0.05 inch smaller than the top to allow for draft and for the strain of pouring. The mold is made in cores or in dry sand. In transverse testing, the bar is placed horizontally on supports 18 inches apart

with a centrally applied load. The tensile strength of cast iron is determined by using a tension test specimen conforming to the dimensions shown in the accompanying illustration. The ends have a standard thread 1⅛ inches in diameter for gripping the test specimen in the tensile testing machine.

Arbor and Mandrel. The names *arbor* and *mandrel* are often used interchangeably to designate a shaft or spindle that is employed for holding bored parts while turning the outside surfaces in a lathe. Tools of this class are known as "mandrels" by most small-tool manufacturers, whereas the spindles or supports for milling cutters, saws, etc., are called "arbors." In a great many machine shops and tool-rooms, however, the term arbor is commonly used to indicate a tool or shaft for holding parts while turning, although some forms of work-holding devices are known as mandrels even by those who ordinarily use the name arbor. A cylindrical piece or other form about which a blacksmith sometimes forges a ring or collar is known as a mandrel, and this name is applied to other classes of tools which are never referred to as arbors.

Arbor Press. Arbor presses provide effective means of forcing arbors or mandrels into drilled or bored parts preparatory to turning or grinding operations on the exterior. In using the arbor press, the work is placed on the base with the hole in a vertical position, and the arbor (which should be oiled slightly) is forced down into it by a ram, operated either by hand or power. Power-driven arbor presses are particularly desirable for large work, owing to the greater pressure required for inserting arbors that are comparatively large in diameter. Arbor presses can also be used for other purposes, such as forcing bushings or pins into or out of holes, bending or straightening parts, or for similar work.

Arc. See Electric Arc.

Archimedean Principle. Two of the fundamental principles of mechanics are frequently spoken of as the *Archimedean principles,* because of their having been originated by Archimedes, the Greek mathematician, who lived in the third century B.C. The first of these principles relates to the equilibrium of a lever, laying down the law that equilibrium will exist when the moments of two weights on opposite sides of the fulcrum are equal. The other principle, more frequently known as the *Archimedean law,* relates to hydrostatics, and pronounces the fact that a body immersed in a fluid loses an amount of weight equal to that of the fluid it displaces.

Archimedean Screw. A device, said to have been invented by Archimedes for raising water, consists principally of a cylinder within which is a shaft with a deep helical thread or groove. The cylinder is placed in an inclined position with its lower end and the screw immersed in water. As the tops of the thread of the screw fit the cylinder closely, water will move upward through the helical chambers formed by the groove or thread when the screw is revolved. The modern screw conveyer, used for raising other materials, is a form of Archimedean screw.

Arch Power Presses. Presses of this class include designs built with a wide bed and arched frame, and a comparatively small slide. Such presses are recommended mainly for large blanking work or shallow forming operations on the lighter gages of metal.

Arcing Grounds. Grounds on transmission and cable systems are frequently the cause of interruptions and damages to apparatus. On overhead lines, the arc to ground breaks insulators and burns off the line conductors. On underground cable systems, the arc to ground quickly burns to the other conductors, causing a short circuit. In addition to these troubles, due to the heat of the arc, the rapid make-and-break of the arc sets up high frequency disturbances which are very dangerous to the system and the connected apparatus. It also causes great annoyance by interfering with the operation of parallel telephone lines.

Arc Light. The light produced by two carbon rods which are connected in an electric circuit so that the circuit is closed by the contact of the tips of the carbon rods. When, after such contact, the carbon rods are again separated, the electric circuit is not broken, if the space between the carbons is not made too great, and an arc of light will be formed between the two points. The light emitted is due to the intense heat of the tips of the carbon rods, and also, to a smaller degree, to the arc itself. It is commonly used in searchlights or spotlights or wherever a light of high intensity is required.

When *direct current* is used for arc lighting, most of the light is produced by the end of the upper or positive carbon rod, or electrode, which acquires a hollow center known as the "crater of the arc." This crater, which throws the light downward, has a temperature of from 5500 to 6000 degrees F., a temperature that is high enough to vaporize carbon. The lower or negative carbon rod or electrode becomes pointed at the same time as the positive one is hollowed out. The carbons are consumed by the passage of the current, the positive electrode being reduced in size about twice as fast as the negative electrode.

When an *alternating current* is used for arc lamps, the upper carbon becomes alternately the positive and the negative electrode and, in this case, no crater is formed; but both electrodes become pointed and the two electrodes give off about the same amount of light and are consumed with about the same rapidity. The great illuminating property of the crater in the direct-current arc, however, is lost, and the light given out by the alternating-current arc is thrown upward as much as downward, which makes it necessary to use a reflector in order to take advantage of the full effect of the light produced.

When carbons, the cores of which have been treated with metallic salts, are utilized, the resulting arc may be used as a source of ultraviolet light, as in sun lamps.

Arc-Light Rope. A wire rope known as *arc-light rope* is made from 9 strands each containing 4 or 7 galvanized wires, and a hemp center. It is used primarily for supporting arc lights, and is made in diameters varying by 16ths from ¼ to ½ inch. The ¼- and 5/16-inch sizes are constructed from strands with 4 wires each, while the larger sizes are constructed from strands having 7 wires each. The breaking strength of arc-light rope is 1125 pounds for the ¼-inch size, 2200 pounds for the ⅜-inch size, and 4700 pounds for the ½-inch size. This rope may be used to advantage for all purposes where a rope is exposed to moisture.

Arc of Action. This term, as applied to gearing, is the angular distance a tooth travels from the point where it first makes contact with its mating tooth until it leaves contact (sometimes called angle of action). *Arc of approach* is the angular distance from the point where tooth contact begins to the intersection of the point of contact with the pitch line. *Arc of recession* is the angular distance from the intersection of the point of contact with the pitch line to the point where tooth contact ceases. The arc of approach and the arc of recession depend upon the pressure angle, the outside radius, the pitch radius, and the base-circle radius.

Arc Sine and Tangent. The expressions "arc sine," "arc tangent," "arc cosine," and "arc cotangent," or, as used in their abbreviated forms, "arc sin," "arc tan," "arc cos," and "arc cot," are used to signify the arc or angle which corresponds to a given value of cosine, cotangent, etc. For example, the sine of 40 degrees is 0.6428; then, arc sin 0.6428 = 40 degrees. The expression "arc sin a" is also written "$\sin^{-1} a$." This latter method, while frequently used, is hardly mathematical in its form, because the use of a negative exponent in this manner might easily lead to confusion and be misunderstood for the expression "$(\sin a)^{-1}$," which means the reciprocal of sin a, or $1 \div \sin a$.

Arc Welding. The principle involved in arc welding consists chiefly in the heating of the work to be welded to a welding heat by means of an electric arc produced or struck (1) between the part to be welded and a carbon electrode; (2) between the work itself and a metallic electrode. When carbon electrodes are used, a metal rod is nearly always employed for feeding additional material into the joint to be welded. When a metallic electrode is used, this electrode is made from a metal which itself is suitable for feeding into the joint to form the material required to complete the weld. See Electric Welding.

Arc-Welding Apparatus, Automatic. The term "automatic arc welder" has been applied to welding apparatus so designed that the wire used in metallic electrode welding is fed mechanically at whatever speed is necessary to maintain a constant arc length and arc voltage. The feeding movement is varied according to the size of the wire and the welding current used, provision being made to obtain the necessary variations. This feeding movement is derived from a small motor which drives the wire-feeding mechanism. This automatic arc welder can be used to advantage in welding long continuous seams on pipes, tanks, boilers, etc., where operation is on a production schedule, and such equipment is also being utilized on railways for building up worn cross heads, guides and wheel flanges.

Arc-Welding Methods. The various methods of electric arc welding may be described as follows:

Carbon arc welding is an arc-welding process wherein a hard carbon or a graphite electrode is used and filler metal, if required, is supplied by a welding rod.

Shielded carbon arc welding is a carbon arc-welding process wherein the molten filler and weld metals are effectively protected from the air by supplemental means.

Metal arc welding is an arc-welding process wherein the electrode used is a metal rod or wire, which, when melted by the arc, supplies the filler metal in the weld.

Shielded metal arc welding is a metal arc-welding process wherein the molten filler and weld metals are effectively protected from the air by supplemental means.

Atomic hydrogen welding is a fusion-welding process wherein the heat of an electric arc between two suitable electrodes is used to dissociate molecular hydrogen into its atomic form, which, on recombining in the molecular form, gives up the energy required to dissociate it, producing a flame of very high temperature and at the same time bathing the molten weld metal in hydrogen. It may be considered as a combination of the gas and arc-welding processes.

Argentan. The name "argentan" is sometimes used for an alloy of varying proportions of nickel, copper, and zinc. This alloy is more commonly known as German silver or nickel-silver, the name "argentan" being used only as a trade name for a certain product of this kind.

Argon. Argon is one of the gaseous chemical elements forming one of the minor constituents of atmospheric air. Its chemical symbol is A; its atomic weight, 39.9; it becomes liquid at a temperature of —186 degrees C. (—302 degrees F.), and solidifies at a temperature of —189 degrees C. (—308 degrees F.). It forms about 0.94 per cent, by volume, of the atmosphere.

Arithmetical Progression. An arithmetical progression is a series of numbers in which each consecutive term differs from the preceding one by a fixed amount called the *common difference, d.* Thus, 1, 3, 5, 7, etc., is an arithmetical progression where the difference d is 2. The difference in this case is *added* to the preceding term, and the progression is called *increasing.* In the series 13, 10, 7, 4, etc., the difference is (—3), and the progression is called *decreasing.*

Armature. Two essential parts of all generators and motors are the *field magnets,* which produce the necessary magnetic flux, and the *armature,* on which the conductors are arranged. The armature of a generator is that part of the machine containing the winding in which the electromotive force is generated. For direct-current machines, the armature is generally revolving, while, for alternating-current machinery, it is mostly stationary, this being preferable as it makes it easier to insulate the windings, which is important, especially in high-voltage machines. To prevent eddy-currents, armature cores are constructed of iron or soft-steel disks from 0.014 to 0.031 inch thick, arranged parallel to the lines of force and perpendicular to the axis of rotation. These disks are insulated from one another by varnish, and the slots are punched on the periphery for holding the windings.

That member of a solenoid or an electromagnetic relay which is moved by changes produced in the electromagnetic field is also called an armature. In a solenoid an armature takes the form of a plunger moving longitudinally, while in a relay it is usually a pivoted arm.

Armature, Motor. The armature of a motor may be divided into four primary parts: (1) the shaft, which transmits the turning moment to the load; (2) the "armature punchings," which are thin disks of magnetic silicon steel assembled on the shaft, insulated from each other to prevent eddy-current losses, held rigidly in the form of a cylinder, and (excepting some types

of motors) having slots cut around the periphery of this cylinder for the reception of the armature windings; (3) the armature windings composed of the current-carrying windings or bars to receive current from the source of power through the commutator or by induction, and (4) the current collecting element which may be a commutator made up of many copper segments insulated from each other but connected to the armature windings, or slip rings, which are merely continuous rings of copper also connected to the armature windings. Both commutator and slip rings serve the purpose of collecting current from the line through brushes which are in contact with them and of delivering this current to the armature windings. Direct current motors are equipped with commutators, while alternating current motors may utilize either commutators or slip rings, or both.

Where all of these parts are not present, as in squirrel cage motors, which require no current collecting element since they are run by electromagnetic induction, or as in very small synchronous motors such as are used in clocks, the rotating member of the motor is more properly called a rotor.

Armature Reaction. The useful magnetic flux in the field of a generator under load, or a motor, is produced by the resultant magnetomotive force of the field-exciting current and of the armature current. *Armature reaction* is the term used to denote the influence of the armature current in modifying the value of the field flux. It is measured in ampere-turns, since it is a magnetomotive force. When the armature current leads the induced electromotive force (emf) in the armature conductors, the armature magnetomotive force (mmf) assists the field mmf and so strengthens the field. When the armature current lags behind the induced emf, the armature mmf opposes the field mmf and so weakens the field. When the current and the induced emf are in phase, the two magnetomotive forces neither assist nor oppose each other, and the influence of the armature reaction is only to distort the main field without changing its value.

The induced armature emf is proportional to the flux per pole, and thus, with leading current in the armature, the induced emf is greater than the open-circuit voltage, and, with lagging current, less than the open-circuit voltage. In the latter case, when load is put on the machine, the field excitation must, therefore, be increased in order to overcome the armature reaction by an amount sufficient to neutralize the armature-demagnetizing magnetomotive force.

The armature reaction of a motor is in the opposite direction to that of a generator running in the same direction, and the field is consequently distorted in the opposite direction.

Armature Windings. Three main types of windings are used on armatures or rotors of electrical machines. One type consists of wire wound coils which are assembled in slotted cores around the periphery of the armature. A second type, known as a squirrel cage, consists of copper or aluminum bars fitted into slots in the rotor and connected at each end by a continuous ring. A third type, used in synchronous motors, has individually wound pole pieces fastened around the rotor core.

Two kinds of winding are employed in the first type: the multiple, parallel or lap winding, and the series, wave or chain winding. The former is used in direct current machines, alternating current motors, rotary converters, induction motors and alternating current generators. The latter is used in direct current generator armatures where a higher voltage is needed in electric railway motors and where the multiple winding is impractical.

The squirrel cage winding may be of a single or double type, the latter consisting of an outer winding or set of cross bars of high resistance and low reactance which carries the starting current, and an inner winding or set of cross bars of low resistance and high reactance which carries the running current.

Armored Cable. Underground electric cables and submarine cables are usually protected from mechanical abrasion by galvanized steel wire, known as armor wire. This is a mild steel wire of uniform diameter, having a tensile strength of about 50,000 pounds per square inch, and an elongation of not less than 10 per cent in 8 inches. Steel tape is also used for mechanical protection. Additional protection is often secured by the use of lead sheathing which excludes moisture.

Armstrong Joint. A two-bolt flanged or lugged connection between pipes for high pressures is known as an Armstrong joint. The ends of the pipe are formed so as to hold properly a *gutta-percha* ring. This form of joint was originally used for cast-iron pipe only. There are various substitutes for this class of joint, many of which employ rubber in place of gutta-percha, and, in some modifications, more than two bolts are used.

Arnold Grinding Gage. This is a size-indicating gage used on grinding machines. It has contact points tipped with tungsten carbide. These points are in contact with the part being ground. The reduction in diameter is shown by a dial gage. In some cases, a single dial gage is used and in others two gages are employed. Sometimes two gages are used when considerable stock must be removed, and roughing and finishing cuts are indicated separately. For example, the first indicator graduated to 0.001 inch may be used for the roughing cuts; then a second indicator, graduated to 0.0001 inch, begins to register for the

final finishing cut. With another arrangement, as applied to crankshaft grinders, one indicator is for pin diameter and a second for pin width. These special crankpin grinding machines are equipped with means for accurately locating the wheel opposite each pin to be ground.

Arsenic. A chemical element, steel-gray in color, having a metallic luster and being very brittle, the symbol of which is As, and the atomic weight, 75.0. The specific gravity varies from 5.4 to 5.95, and the melting point is 850 degrees C. (about 1560 degrees F.). It is a constituent of certain minerals containing iron, nickel, and cobalt, and is also found in small quantities in nearly all iron pyrites.

Asarcoloy No. 7. Bearing metal having Brinell hardness at 82 degrees F. of 33; at 390 degrees F., 7. Yield point in tension, 11,700 pounds per square inch. Elongation at 82 degrees F., 19; at 390 degrees F., 111. Compressive strength at 82 degrees F., 21,800 pounds per square inch; at 390 degrees F., 4400 pounds per square inch. Meets the demands for a bearing metal for high-speed, high-compression engines. Since the alloy bonds directly with steel, the same composition as is used for the bearing proper can be used for bonding. The nickel penetrates the steel slightly, as when welding nickel to steel.

Asbestine. A material used in paints for protecting iron and steel against corrosion, consisting of a natural silicate of magnesia. When used in paints, it prevents the settling of other pigments, and strengthens the paint film. It grinds in 32 per cent of oil. It also occurs in the form known as *talcose.*

Asbestos. Asbestos is a fibrous mineral which is noncombustible and therefore has many uses in the industries for fire protective purposes. The composition of asbestos varies somewhat according to the source from which it is obtained. Analyses made of various grades indicate that it contains about 40 per cent of silica, from 42 to 43 per cent of magnesia, from 1 to 3 per cent of ferrous oxide, from 1 to 2 per cent of alumina, and from 13 to 14 per cent of water. Asbestos was formerly a rare curiosity, but now it is applied to a great variety of uses in industrial arts, and these applications are constantly increasing. Its value in the industries depends not only upon its property of withstanding a high temperature, but also upon its low thermal conductivity, making it an excellent heat-insulating material for boilers and steam pipes. It also partially resists the action of acids, and is used as a filtering material for corrosive liquids. It is made up in a number of different forms, such as yarn, felt, paper, boards, etc., and is employed in many fireproof

cements. Asbestos is also used as an electric insulating material, but loses its insulating qualities at about 1800 degrees F., although it will recover these qualities, when cooled. Its usefulness as an electrical insulation is impaired somewhat by its hygroscopic property and the presence of iron oxide particles which are difficult to remove. It also loses its mechanical strength at the temperature mentioned, and will melt at about 2400 degrees F. As a non-conductor of heat, it has been applied to a large extent as an insulating material in electric heating devices of various types.

Ashberry Metal. Ashberry metal is a composition consisting of 77.8 per cent of tin; 19.4 per cent of antimony; and 2.8 per cent of copper. It belongs to the class of metals generally known as *Britannia metals*. An alloy of the same composition, except that zinc is substituted for the copper, is also known as ashberry metal.

Asphaltum. Asphaltum or "asphalt" may be either a natural product or the heavy residuum from petroleum. The latter are known as oil asphalts and are obtained largely from mid-continent, Texas, California and Mexican petroleums. Asphalt is a black non-oxidized bituminous hydro-carbon, ranging from semi-fluid to hard in consistency.

Asphaltum is extensively used for flooring and paving purposes, and is also employed as a preservative coating for iron and steel. It is applied either by dipping the object to be coated into a molten bath of asphaltum, as in the case of water pipe, or by pouring the asphaltum onto the surface to be protected, as in the case of bridge floors. The asphaltum to be used for the protection of iron and steel should be applied at from 300 to 400 degrees F. It should be slightly elastic, when cold, and should not soften appreciably at 100 degrees F. The surface to which it is applied should be dry and hot, and the coating should be of considerable thickness.

Asphaltum is also used in engineering as a component of waterproof cements, and also as a waterproof coating for a number of purposes. Asphalt compositions are also to some extent acid-proof, and are used as cement in pipe lines, tanks etc., where acids or acid vapors must be resisted. Pure asphalt softens at from 200 to 210 degrees F., and is not recommended in cases where it is subjected to heat or to high stresses. As an electric insulating material, asphalt is used to a great extent as insulation containing asphalt possesses a high resistance to puncture, in addition to flexibility and mechanical toughness. It is also cheap and is not affected by moisture. It is used for the manufacture of insulating varnishes, for the impregnation

of insulating materials in order to make them waterproof, and as an insulating covering for cables. The puncturing voltage varies from 5000 to 15,000 volts per millimeter (0.039 inch).

Assembly, Progressive. See Progressive Assembly.

Assembly, Selective. See Selective Assembly.

Atmospheric Line. An atmospheric line is one drawn on an engine "work diagram," parallel to the line of absolute vacuum and at such a distance above it as to represent 14.7 pounds pressure per square inch.

Atmospheric Pressure. The normal atmospheric pressure at sea level is generally assumed to be 14.7 pounds per square inch, which corresponds to 29.92 inches of mercury. Frequently, however, the atmospheric pressure is assumed to be the pressure of a 30-inch vertical column of mercury at 32 degrees F., which corresponds to 14.73 pounds per square inch. In the countries using the metric system, the pressure of an atmosphere equals 760 millimeters of mercury (29.92 inches) at 32 degrees F. This corresponds exactly with a pressure of 14.7 pounds per square inch, and is the value generally used in engineering calculations. The pressure in atmospheres is frequently used as a measure for air, steam, or liquid pressures. For example, a pressure of five atmospheres would equal $5 \times 14.7 = 73.5$ pounds per square inch. In calculations where extreme accuracy is not required, it is often assumed that an atmosphere equals 15 pounds per square inch. This makes it easier to perform calculations, five atmospheres being then equal to 75 pounds per square inch.

Atom. An atom is the smallest basic unit of a chemical element. It is composed of a positively charged nucleus made up of a proton (in the case of the hydrogen atom) or a group of protons and neutrons. This is surrounded by an electron (in the case of the hydrogen atom), or a group of electrons of equal negative charge. The size of an atom is in the order of 10^{-8}cm outside diameter, and its nucleus 10^{-12}cm outside diameter.

Atomic Hydrogen Welding. A fusion welding process wherein the heat of an electric arc between two suitable electrodes is used to dissociate molecular hydrogen into its atomic form, which on recombination in the molecular form gives up the energy required to dissociate it, producing a flame of very high temperature and at the same time bathing the molten metal in hydrogen. It may be considered as a combination of the gas and arc welding processes.

With atomic hydrogen welding, metals can be fused without oxidation, welding being performed in some cases on metals as thin as paper. Since atomic hydrogen is a powerful reducing agent, it reduces any oxides which might otherwise form on the surface of the metal. Alloys containing chromium, aluminum, silicon, or manganese can be welded without fluxes and without surface oxidation.

Atomic Weights. Atoms are too small to have their absolute weights determined; therefore, hydrogen, being the lightest known element, was first taken as a unit, and the atomic weights of all other elements were compared with this. It was supposed that, when the atomic weight of hydrogen was taken as the unit, the atomic weight of oxygen was 16, so that atomic weights, expressed on the basis of the hydrogen atomic weight being equal to 1, would also compare directly with the atomic weight of oxygen, expressed as 16. Later investigations have shown, however, that this ratio between the atomic weights of oxygen and hydrogen is 15.88 to 1. The leading chemical societies of the world, however, decided to retain the value of the atomic weight of oxygen as 16, and the atomic weights based on this standard are known as "international atomic weights." It has been found that the specific heat of an element multiplied by its atomic weight is a constant closely approximating the value 6.25. Upon this fact a method of determining atomic weight has been based, as the atomic weight may be found approximately by dividing 6.25 by the specific heat.

Audio Frequency. An audio frequency is a frequency corresponding to a normally audible sound wave. Audio frequencies range roughly from 20 to 15,000 cycles per second.

Auger Speeds. Auger speeds depend largely upon the condition of the wood in regard to seasoning. For example, with the same wood, say pine, speeds could vary by as much as one-third for samples that were very resinous or not properly seasoned. A hard wood, say mahogany, can be satisfactorily cut at a heavier feed and quicker speed than a soft wood badly seasoned or spongy. With spongy woods, there is often difficulty in clearing the chip or core, and this limits the speed. Again, many woodworking machines have an insufficient range of speeds, and small augers have to be underspeeded to avoid overspeeding the large ones. The following speeds for average woods may be taken as a guide for use with a good quality machine and auger: ½-inch augers, 200 revolutions per minute; ¾-inch augers, 1600; 1-inch augers, 1300; 1¼-inch augers, 1200; 1½-inch, 1100; and 2-inch, 1000.

Austempering. A process whereby a ferrous alloy is quenched from a temperature above its transformation range at a rate which prevents formation of high-temperature transformation products and then keeps the alloy at a temperature above which no martensite forms and below which no pearlite forms until the transformation is complete.

Austenite. Austenite is the solid solution of iron carbide in steel heated above a temperature of about 1300 degrees F. (about 700 degrees C.). Normally, when the metal cools below this point, austenite divides into *ferrite* and *cementite*, the former being practically pure iron and the later being iron carbide. The dissolution may be avoided partly by suddenly cooling the steel in water, and completely by adding manganese, nickel, tungsten, or molybdenum. Some of the manganese and nickel steels are manganiferous and niccoliferous austenite. Austenite is non-magnetic; hence, steel heated to the hardening temperature is non-magnetic. Austenite is very malleable, and, at the same time, very hard. As the sudden quenching of iron, as when hardening high-carbon steel, only partly preserves the austenite, carbon steel is strongly magnetic.

Autogenous Welding. See Gas Welding.

Automatic. The term "automatic" is often used as a noun in the machine-building industry, to indicate any kind of automatic turning machine, especially an automatic screw machine or automatic chucking and turning machine of the turret lathe class. See Automatic Machine Tool Classification.

Automatic Dies. See Dies for Thread-cutting.

Automatic Steam Engines. Many stationary steam engines have valves that are controlled by governors of the shaft or flywheel type, the arrangement being such that a practically uniform speed of the engine is maintained automatically by the direct action of the governor upon the valve. For instance, if the engine speed varies, the position of the governor eccentric is changed, which, in turn, causes a change in the position of the valve, thus altering the point of cut-off and either reducing or increasing the speed, depending upon whether it is above or below the normal speed. Engines of this general type are often called "automatic" engines. There are various types of governors for engines of this class, and the valves also vary considerably, some engines having a single slide valve controlled by a shaft governor, whereas others have a main valve provided with an auxiliary "riding" or cut-off valve, which is controlled by the governor. The change in the position of the governor

eccentric for varying the valve travel and point of cut-off is effected in different ways. The eccentric may be shifted by changing the angle between it and the crank, or the eccentricity alone may be changed, or both the angularity and eccentricity may be changed simultaneously. The first two methods are rarely employed with a single valve; in fact, most fly-wheel governors are so arranged that, when the engine speed increases, the angle between the crank and the eccentric, as well as the eccentricity, is changed at the same time.

Automatic Gear-Cutting Machines. Machines of the formed-cutter types are commonly known as "automatic" gear-cutting machines because, after the gear blank or blanks are in the cutting position and the machine is properly adjusted, all the gear teeth are cut automatically without further attention on the part of the operator. There are certain other types of gear-cutting machines which also operate automatically, except for the insertion and removal of the work, but the term "automatic" is not used in designating them to the extent that it is applied to spur-gear machines of the formed-cutter type.

The general characteristics of these automatic spur-gear machines include a main spindle for holding and driving the work-holding arbor; a cutter-slide arranged to move parallel with the axis of the work-spindle; a mechanism for feeding the cutter-slide at a suitable rate and returning it to the starting point; and a mechanism for indexing the gear blank after each tooth space is milled.

Automatic Lathe. The automatic lathe is so designed that all of the tool movements are automatically controlled, although the work must be inserted and removed by an attendant. The original machine in this field is the Fay automatic lathe. This type of machine has a headstock and tailstock for driving and supporting the work, the same as on a standard engine lathe, and, in addition, it is equipped with a carriage and supplementary facing and forming tools that are operated automatically. This machine is used for turning rough forgings which may be held on centers, but its principal use is for work held on an arbor; therefore, it is primarily a second-operation machine, completing work that has previously been chucked and otherwise partly finished on the drill press or turret lathe.

Automatic Machine Tool Classification. The term "automatic," as applied to various classes of machine tools, does not always have the same meaning, and a machine which one manufacturer classifies as automatic would be considered semi-automatic by another manufacturer. For instance, some machines

which are designed to perform a certain cycle of operations, but are not capable of presenting unfinished parts to the tools, may be referred to as automatic machines. While such a machine is automatic or self-moving in that it controls the movements of the cutting tools through one cycle of operations, the attention of an operator is required, so that such a machine is really only semi-automatic.

There are other types of machines which not only control all the movements of the cutting tools, but are equipped with work-feeding mechanisms so that, when one part has been finished, other duplicate parts may be produced automatically. The operation of such a machine is continuous until it needs to be supplied with raw material, which may either be in the form of bar stock, or separate castings or forgings, when a magazine feeding attachment is used. A machine of this type is automatic in the sense that it repeatedly performs all of the necessary operations, which include ejecting the finished work and presenting a new piece or length of stock to the tool. Thus when a machine is capable of automatically producing duplicate parts repeatedly, it is universally referred to as automatic, whereas, if it simply performs a complete cycle of machining operations, but requires the attention of an operator each time a part is finished, it may be considered automatic by some, and semi-automatic by others. In some cases, a machine of the latter class is termed "automatic," while one that is capable of continuous operation is known as a "fully automatic."

Automatic Screw Machine. The original field of the automatic screw machine was, as its name implies, the making of screws. This field was quickly enlarged to include the making of all kinds of small nuts, washers, pins, collars, etc., and, at the present time, machines of this class are capable of a great variety of operations, not only on parts which are turned from bar stock, but on separate castings or forgings that are automatically fed to the machine by a special feeding mechanism.

Characteristic features of screw machines in general are means for automatically locating successive tools in the correct working position, the automatic changing of feeds and speeds to secure economical operation, and the presenting of new stock to the tools for a similar series of operations. These various movements, which are entirely automatic, are obtained principally from cams which are rotated at pre-determined speeds, and are so formed and set relative to one another that the parts of the machine which they control all operate at the proper time, and at suitable speeds. There are two general classes of screw machines, one class having a single work-spindle and the other,

several work-spindles—usually four, five or six spindles. Each spindle of the multiple-spindle type holds a bar stock, and tool-holders feed tools forward to operate on these bars of stock held in the opposing work-spindles. After a tool-holder has concluded its working stroke and returned to the starting position, the work-spindle carrier or head is revolved, bringing each bar of stock to the next tool in rotation. The final tool position provides for a cut-off blade, and a complete piece is finished and cut off at each indexing. One or more forming slides also operate at the different spindle positions if necessary. With this type of machine, all the cutting tools are working on each feeding stroke, as each has a bar of stock presented to it, whereas, with a single-spindle machine, the various tools of the turret operate successively on a single bar of stock.

The time required to complete a part on a single-spindle machine is equal to the total time necessary for all of the individual operations, which includes the time for withdrawing the tools at the completion of the cut, indexing the turret and presenting the succeeding tools to the work. With a multiple-spindle machine, the total time required to complete a piece is equal to the time necessary for the longest single operation plus the time for the idle movements; in some cases, the time is reduced by dividing the longest operation into two operations.

Automatic Screw Machine Origin. A great field was opened in machine tool development by the invention of the "automatic turret lathe" by Christopher N. Spencer, who was then connected with the Billings & Spencer Co. The idea of designing an automatic turret lathe or screw machine was suggested to Spencer by another machine which he had invented for turning spools for sewing machines. The action of this automatic turret lathe was controlled by a cam cylinder provided with flat strips adjustable according to the movements required, but this exceedingly important feature was overlooked by the patent attorney. This machine proved so successful for making screws automatically that Spencer severed active relations with Billings & Spencer Co. in 1874 and soon afterward established, with others, the Hartford Machine Screw Co.

Automatic Threading Lathe. The automatic type of threading lathe is especially adapted to threading duplicate parts in quantity, because the movements of the lathe are all automatically controlled after the work is placed in position and the lathe is started. This mechanical control, which governs the forward and return movements of the carriage and the movements of the tool, insures more rapid and continuous operation than would be obtained with an ordinary engine lathe.

Automation. Automation is the automatic handling of workpieces into, between, and out of machines.

The foregoing statement was the meaning of the word "automation" as it was coined by D. S. Harder, vice-president of the Ford Motor Company in 1947. However, to many people it goes much further to mean the actual production of many items by automatic means with little or no human help.

The first major step in this type of production was the introduction, about 1940, of the automatic transfer machine. It consisted of a group of drilling, reaming, tapping, and milling machines arranged along both sides of an automatic conveyor. The work was attached to a special locating plate and pushed along a section of roller conveyor until it was engaged by a catch on a reciprocating transfer bar. The bar pulled the work into its approximate position at the first machine station, then hydraulically operated pins were raised to engage holes in the locating plate for exact positioning. Hydraulic clamps then locked the plate and the first set of tools performed the first machining operation. When the operation was complete, the tools withdrew, the clamps released, and the work was pulled into the second position by the transfer bar. At the same time, a new workpiece was pulled into the first position. Over a hundred operations were performed on this first machine on aircraft engine cylinder heads, including turning the work upside down for operations on the inside.

All operations were interlocked, so that the machine could not operate unless every workpiece was properly positioned and locked, and could not transfer unless every tool was clear and all clamps and locating pins released. If the machine failed to operate, the operator pressed a button on the control pulpit, causing a series of small lamps to light. A lamp that failed to light indicated that there was trouble at the particular station to which that lamp was connected, and a maintenance man was called to correct it.

The weakness of the system lay in the fact that if a tool broke or became worn, there was no way to detect it until inaccurately made pieces were detected by inspection at the end of the line. To remedy this a schedule was drawn up to show the expected tool life of each tool, based on the number of pieces it had machined. At appropriate times the machine was stopped and a tool replaced, regardless of its condition.

Once established, the development of the in-line transfer machine was very rapid, and it is now applied to a variety of parts. It has been found that in many cases work can be transferred and positioned without the necessity of mounting it on a special locating plate, and automatic inspection stations are incorporated at various places along the line so the work can

literally inspect itself as it goes along. If a part fails to pass inspection, the machine will stop, and a visible and audible signal is given to the operator. For example, after holes have been drilled, a jet of compressed air blows out the chips, and a metal finger probes the hole to make sure it is to the proper depth, or that it is not plugged by a broken drill, or tightly packed chips. If the work passes this inspection, it can pass along to the tapping operation; if it does not, the machine stops until the trouble is remedied.

Tool life is checked by a special control board on which is mounted a complete set of spare tools. When the time comes for a tool change, the machine stops automatically and a signal lamp lights up at that particular tool on the control board. The operator then removes the spare, slips it into its socket on the machine, and operations continue. The worn tool goes to the tool room to be sharpened, is adjusted to a special tool-setting gage, and replaced on the control board. This permits the operator to change tools without time-consuming adjustments and insures the machine's running for the maximum working time.

Modern transfer machines are not necessarily arranged in a straight line. They may be in the form of a rectangle or a U, depending on the floor space available and the general arrangement of the production line. They may have dozens of stations with heavy-duty machine heads, as for performing all the operations on an automobile engine block, or they may be only a few feet long with light-duty tooling for small parts, such as carburetors or office-machine parts.

A variation of the in-line machine is the rotary-table type in which a series of machine heads are arranged around the outside of a circular table which is rotated or indexed a pre-determined distance at each machine cycle. A number of holding fixtures are attached to the table, one for each machine head and one at the opening or loading position. The operator places a part in the fixture at the loading position and presses the start button. The table indexes to position the work at the first machine head which then goes into action to perform the first operation. At the same time, the second and succeeding heads perform their functions on the workpieces which the table has presented to them. When a part has made a complete circuit of the table, it arrives at the loading position where it is removed and another part inserted. This series of operations continues as long as the operator keeps feeding fresh work into the machine.

Although the transfer machine was a tremendous forward step in increasing productivity, it did not entirely overcome the major bottleneck of all machine shops—that of handling the work. True, it saved handling from machine to machine, but

someone still had to load the work at the first station and unload it at the last, and the work had to be moved to and from the transfer machine itself. The conveyor line furnished part of the answer but there was still the human element to be reckoned with. Furthermore, developments in new cutting materials and new concepts of cutting speeds had brought about a condition in which the machine was capable of turning out the work faster than a man could load and unload it. This meant that machines were not being used to their maximum capacity and handling time was out of all proportion to machining time. What was needed was some completely automatic system of handling that could keep pace with the machine. Out of this need was born the modern concept of automation.

One of the first applications was the handling of steel sheets into and out of large presses at the Ford Motor plant. A mechanical hand picked up a sheet and positioned it in the blanking die, then pushed the blank onto a chute from which it was picked up by a second mechanical hand and placed in the drawing die. Meanwhile, scrap was chopped into pieces and dropped into a conveyor under the press to be carried away. The process continued until the final part was discharged to another conveyor without once being touched by the machine operator.

In another arrangement, also at Ford, five presses were arranged in a circle surrounding a special handling mechanism. Split axle-housing tubes were loaded automatically into the arms of the handler and moved progressively from one machine to the next until they were discharged completely formed from the final press. Only one man was required to supervise the operation of the entire unit.

The advantages of this mechanized handling were so apparent that engineers began to look for other opportunities to apply the principle. Lathes, for example, offered a real challenge. Work could be brought to the machine, loaded, turned, and unloaded. Tremendous savings would be possible. So too with millers, drills, broaches, grinders, and all the varied machines required for quantity production. Within months, designers all over the country were devising loaders, feeders and unloaders to convert standard machines for automatic operation, and machine tool builders were modifying their machines so the various devices could be attached readily.

Meanwhile, machine tool designers began work on completely new machines in which the automation devices were built-in as a part of the machine itself. Gone were the limiting factors of human operation; speeds and feeds could be stepped up to unheard-of rates; and the working areas could be safely enclosed.

But now a new problem arose. For fully automatic operation, it was essential that parts leaving one machine be exactly the

right size for loading automatically into the next machine. For example, suppose the first machine were required to rough turn a shaft to 2.125 inches in diameter, then pass it to a second machine for a fine finishing cut to 2.115 inches. A certain tolerance is permitted, say plus or minus 0.002 inch. This means that the shaft can be as large as 2.127 or as small as 2.123 when it leaves the first machine. Similarly, a certain tolerance must be allowed for the finishing machine, say plus or minus 0.001 inch. Thus, if the first machine makes the shaft 2.127 and the second finishes it down to 2.114, the maximum amount of stock the second machine will have to remove is 0.013 inch, or a depth of cut of 0.0065 inch.

But suppose the roughing tool wears very rapidly or even breaks, and a part leaves the first machine with a diameter of 2.150 inch. There would be far too much stock for the finisher to remove, so either the finisher would wear excessively or break, or the work would be spoiled. In an extreme case, the machine might break down.

To avoid this, an automatic gage can be installed on the discharge side of the first machine to inspect the one or more dimensions involved. If the work passes this inspection, it can move on to the next machine; if it will not pass, the gage will hold the work, stop the machine, and signal the operator who must then locate the cause of the trouble and make the necessary corrections to the tools.

Size control by this method is fairly simple and reasonably satisfactory, but it leaves something to be desired. One workpiece, the one held by the gage, will have to be scrapped or reworked, and the machine has to be stopped while the tools are being adjusted. This means that all the machines that handle the work after this one are also stopped because they are not receiving fresh work; and preceding machines must also be stopped to prevent their piling up work that has no place to go, unless suitable "banks" have been provided.

The next step, therefore, in automatic control is to let the gage actually control the machine. To do this we "steal" part of the tolerance and set the gage to reject work that is slightly above the low limit or below the high limit. Using the same example as before, we might set the gage to reject work that measures 2.126, even though 2.127 is acceptable by the next machine. As long as work remains below this dimension the gage will pass it, but as soon as a piece comes through that measures 2.126 the gage's "memory cells" go into operation. It passes the part because it is still below 2.127 and therefore acceptable by the second machine, but it remembers that it has passed it. If the next part is also 2.126 the gage will pass it also. But then its automatic correction mechanism goes into action

to adjust the tool so that the third piece will be made smaller. If the third piece is satisfactory, the memory cells cancel out until another oversize piece again activates them. If the third piece is not satisfactory, the gage will either make another correction or stop the machine.

This principle is employed on the self-resetting lathe, which not only adjusts the tools to compensate for wear but actually changes them if they become too worn for further use. Instead of a conventional tool post, this machine has a drum in which eight or ten identical tools are mounted and carefully adjusted. The first tool operates until the gage signals that the work is approaching oversize. Then that tool is advanced 0.0005 inch and continues to work until the next signal is received. After it has been advanced six times it will be too badly worn to be of further use, so the next time, instead of advancing, it withdraws all the way to the starting point and the drum indexes to bring the second tool into cutting position. This continues until the last tool in the drum has made its last advance. Then, instead of bringing the worn number one tool into position, the machine stops and flashes a warning signal to the operator. Changing the tool takes only a few minutes. The operator removes one nut, lifts off the used drum, replaces it with another drum of sharpened tools, and tightens up the nut. Then he presses the start button and the machine continues as before.

On machines of this type, gaging is not confined to the work; the tool itself is also gaged. Thus, if a tool should break, the machine does not wait for a bad piece to be produced, but automatically indexes the drum to bring a new tool into place.

In a lathe operation there is not too much likelihood of a part being turned undersize unless a tool has been improperly adjusted in the first place. Consequently, if the gage should find an undersized piece it will automatically stop the machine.

Gaging equipment may be operated by air or it may be electric or electronic, and the control circuit includes a cycle counter that can be adjusted to call for a tool advance from one to five times before the tool actually moves. This minimizes the possibility of a chip catching between the work and the gage to give a false reading, and thus cause more frequent changes of tools than is really necessary. Use of this feature, however, depends upon the accuracy required in the work.

Self-resetting is not confined to lathes but can equally well be applied to grinders and other machines. In the case of grinders, provision is made to advance the wheel to compensate for wear, and also to dress it at specified intervals and then compensate for the amount dressed off. On one such machine for grinding crankshafts the diameter is checked by an air gage during grinding, and the wheel is fed automatically in accord-

ance with this measurement. At the same time, the speed of the wheel-driving motor is adjusted to compensate for the change in wheel diameter so as to maintain constant surface speed.

Autothermic. Steel strips covered by aluminum sections for their entire length. Since aluminum expands more than steel due to temperature increases, the strips will assume a curved form when heated. Used in connection with high silicon-aluminum pistons in combustion engines to increase the expansion of the piston skirt in the direction parallel to the piston-pin, and to reduce the expansion along the diameter perpendicular to the piston-pin, thus causing a piston skirt ground oval when manufactured to assume a cylindrical form at engine working temperature.

Auto-Transformers. An auto-transformer has but one continuous winding which serves as both primary and secondary. A tap is brought off from some point in the winding and the voltage between this point and the end of the winding will be some fraction of the voltage between the terminals of the entire winding. Usually the ratio of primary to secondary is close to unity. This type of construction permits a considerable saving in copper over the conventional two-winding type of transformer. There is no insulation between the high- and low-voltage circuits, and therefore, the use of an auto-transformer is confined to those cases where this feature is not objectionable. Most of the phase connections used with transformers are also possible with auto-transformers which are used wherever their primary and secondary voltages are near enough in value to make their use permissible. Auto-transformers are used for furnishing reduced starting voltages to synchronous or induction motors and rotary converters. With a variable tap switch to provide different ratios, they may be used as voltage compensators to provide the exact potential required for operating certain devices at maximum efficiency or accuracy.

Avogadro's Law. A principle in physics which states that equal volumes of all gases having the same temperature and subjected to the same pressure contain the same number of molecules.

Avoirdupois or Commercial Weight. 1 gross or long ton = 2240 pounds; 1 net or short ton = 2000 pounds; 1 pound = 16 ounces = 7000 grains; 1 ounce = 16 drachms = 437.5 grains.

1 ton (of 2240 pounds) = 1.016 metric tons = 1016 kilograms; 1 pound = 0.4536 kilogram = 453.6 grams; 1 ounce avoirdupois = 28.35 grams; 1 ounce troy = 31.103 grams; 1 grain = 0.0648 gram.

The following measures for weight are now seldom used in the United States: 1 hundred-weight = 4 quarters = 112 pounds (1 gross or long ton = 20 hundred-weights); 1 quarter = 28 pounds; 1 stone = 14 pounds; 1 quintal =100 pounds.

Axiom. An axiom, in mathematics, is a self-evident general proposition which is accepted as true without a proof. The twelve axioms which are the foundation of geometry, and of the mathematical science in general, are: 1. Quantities which are equal to the same quantity are also equal to one another. 2. If equal quantities are added to equal quantities, the totals are equal. 3. If equal quantities are taken from equal quantities, the remainders are equal. 4. If equal quantities are added to unequal quantities, the totals are unequal. 5. If equal quantities are taken from unequal quantities, the remainders are unequal. 6. Quantities which are double the same quantity are equal to one another. 7. Quantities which are one-half of the same quantity are equal to one another. 8. Geometrical quantities which coincide with one another, that is, which actually fill the same space, are equal to one another. 9. The whole is greater than any of its parts. 10. Two straight lines cannot enclose a space. 11. All right angles are equal to one another. 12. If a straight line intersects two other straight lines, so as to make the two interior angles on the same side of it taken together less than two right angles, then these straight lines, if continually produced, must meet upon the side on which the angles are less than two right angles.

Axis of Equilibrium. In a floating body at rest on the water, a line joining the center of gravity of the body with the center of buoyancy. This line is always vertical. See Buoyancy.

Axle Lathes. Axle lathes are equipped with two tool carriages, so that both ends of an axle may be turned at the same time. On most lathes of this class, the axle is revolved by a special driving head, which is located in the center of the lathe bed. The axle is gripped in the middle by clamps on the head, and the ends are supported by tailstocks. With this arrangement, the work is rotated on "dead centers" (non-rotating centers), which is desirable, and the ends are accessible for the turning operations. The central driving head is operated through gearing from a shaft which extends along the bed and is rotated through additional gearing at the headstock end, either by a belt pulley or a direct-connected motor.

B

Babbitting Mandrel. An arbor or rod used when lining bearings with babbitt metal, the mandrel corresponding to the shaft which is to have its bearing in the lining.

Babbitt Metal. Babbitt is the name given to a large variety of white metal alloys used as linings for bearings. The name is derived from that of the inventor, Isaac Babbitt, who, in 1839, obtained a patent for a special type of bearing enclosing a soft metal alloy. The exact composition of the original babbitt metal is not known, but the ingredients were copper, tin, and antimony, in approximately the following proportions: 89.3 per cent tin; 3.6 per cent copper; and 7.1 per cent antimony. This metal possesses great anti-frictional qualities, but the high percentage of tin makes it expensive and has led to the substitution of other metals which are marketed under the name of "babbitt metal." These cheaper grades, when properly made, are superior to the original babbitt metal for some purposes. The composition of babbitt metal should be varied according to the pressure to which it will be subjected and the speed of the rotating member; the size of the bearing and thickness of the babbitt metal lining should also be considered. While it is not necessary to use a different composition for each slight variation, a different grade is preferable when the conditions are radically different.

Babbitt Metal for Heavy Pressures. The following composition gives a rather hard babbitt metal which may be used for lining connecting-rod and shaft bearings subjected to heavy pressures. This composition conforms to the S.A.E. standard specification for No. 11 babbitt, and is suitable for die-castings.

Cast Products: Tin, minimum, 86 per cent; copper, 5 to 6.5 per cent; antimony, 6 to 7.5 per cent; lead, maximum, 0.35 per cent; iron, maximum, 0.08 per cent; arsenic, maximum, 0.10 per cent; bismuth, maximum, 0.08 per cent; zinc and aluminum, none.

Ingots: Tin, minimum, 87.25 per cent; copper, 5.5 to 6 per cent; antimony, 6.5 to 7 per cent; lead, maximum, 0.35 per cent; iron, maximum, 0.08 per cent; arsenic, maximum, 0.10 per cent; bismuth, maximum, 0.08 per cent; zinc and aluminum, none.

Babbitt Metal for Light Pressures. A cheap babbitt metal intended for large bearings and light service and which is also

suitable for die castings, has the following composition, the figures representing percentages:

Cast Products: Tin, 4.50 to 5.50; antimony, 9.25 to 10.75; lead, maximum, 86.00; copper, maximum, 0.50; arsenic, maximum, 0.20; zinc and aluminum, none.

Ingots: Tin, 4.75 to 5.25; antimony, 9.75 to 10.25; lead, maximum, 85.50; copper, maximum, 0.50; arsenic, maximum, 0.20; zinc and aluminum, none.

This is the Society of Automotive Engineers (S.A.E.) specification No. 13. This metal should not be used as a substitute for a babbitt with a high tin content.

Babbitt Metal for Medium Pressures. A relatively cheap babbitt metal intended for bearings subjected to moderate pressures and one that is also suitable for die castings has the following composition, the figures representing percentages:

Cast Products: Antimony, 9.50 to 11.50; copper, 2.25 to 3.75; lead, maximum, 26.00; tin, minimum, 59.50; iron, maximum, 0.08; bismuth, maximum, 0.08; zinc and aluminum, none.

Ingots: Antimony, 10.25 to 10.75; copper, 2.75 to 3.25; lead, maximum, 25.25; tin, minimum, 60.00; iron, maximum, 0.08; bismuth, maximum, 0.08; zinc and aluminum, none.

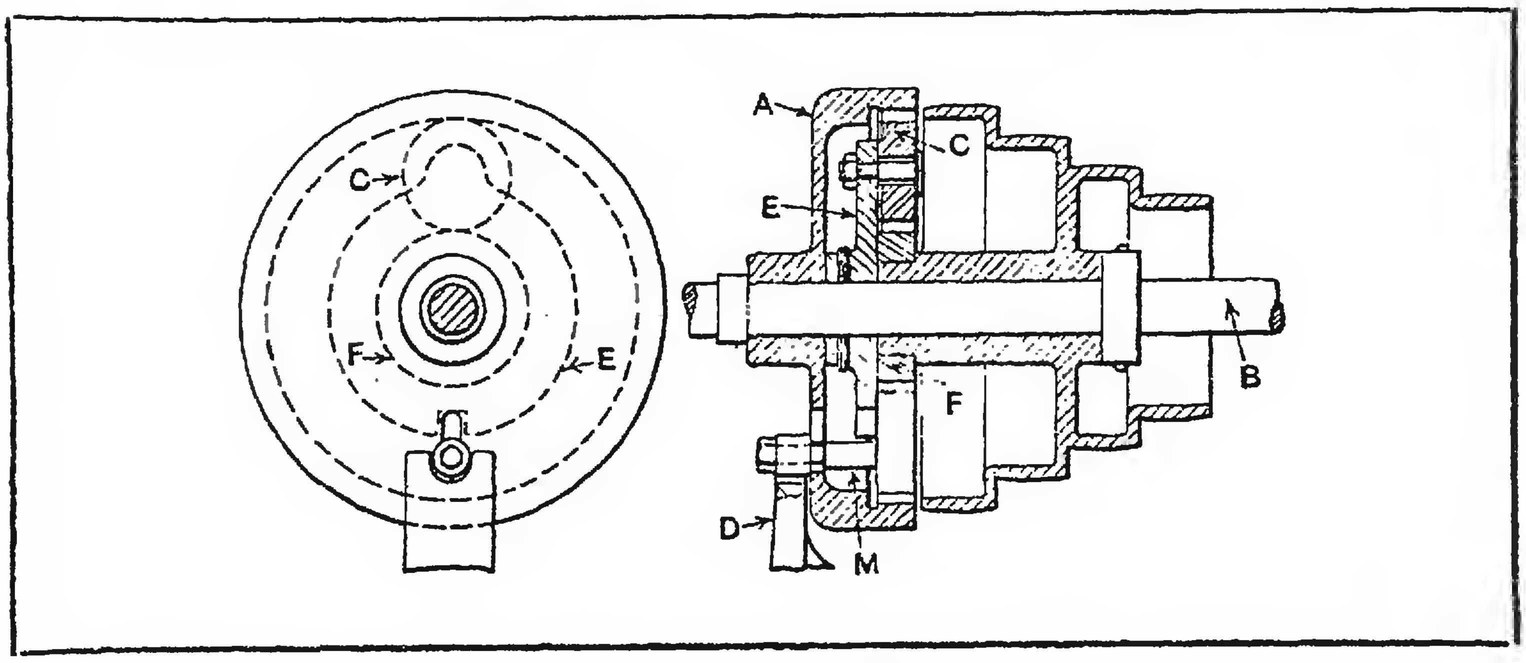
This is the Society of Automotive Engineers (S.A.E.) standard specification No. 12.

Back Cone of Bevel Gears. The back cone of a bevel gear is the cone generated by swinging the back cone radius about the axis of the gear. The *back cone radius* is the distance perpendicular to the pitch surface from the pitch line to the axis. (This distance is also called virtual pitch radius.)

Back-Gears. Back-gears are applied to various types of machine tools such as lathes, boring mills, drill presses, etc., in order to increase the range of speeds obtainable with a cone-pulley drive. In the case of an engine lathe, if a slower speed is required than can be obtained with the belt on the largest step of the cone, the latter is disconnected from the spindle, and the back-gears are moved into mesh; the drive is then from the cone-pulley through the back-gears and to the spindle. The fastest speed with the back-gears in mesh is somewhat slower than the slowest speed when driving with the back-gears out of mesh.

Double Back-gearing: Many lathes have *double back-gears,* so that two ranges of speed may be obtained in addition to those secured by shifting the belt on the cone-pulley. For instance, if there are four steps on the cone-pulley, twelve changes of speed would be available if the lathe were equipped with double back-gears. These gears may be used merely to increase the number

of speed changes, or the primary object of including double back-gears in the design of a lathe may be to increase the driving



Differential Back-Gearing

power without sacrificing, appreciably, the number of speed changes, by reducing the number of steps on the cone-pulley and increasing their width, so that a much wider driving belt may be used.

Triple-geared Headstocks: That type of gearing for lathe headstocks which has two back-gear shafts, one of which carries a pinion that may be engaged directly with an internal gear on the faceplate, is commonly known as *triple gearing.* This term, however, as used by different lathe manufacturers, is not applied to the same arrangement of gearing, and does not invariably mean that the number of speeds may be tripled.

Back-Gears, Differential Type. The planetary form of gearing in which one or more gears not only revolve about their own axes, but turn bodily about a meshing gear, is sometimes applied to speed-changing mechanisms. The illustration shows the application of a planetary gear to the cone-pulley on an upright drilling machine for doubling the range of speeds the same as with ordinary back-gears; this form of mechanism is often called "differential back-gearing." The cone-pulley and the casting *A* are both free to rotate upon the shaft *B*. Gear teeth are cut on the inside of casting *A*, thus forming an internal gear. The planetary pinion *C* rotates upon a pin fixed in disk *E*, which is keyed to shaft *B*. The gear *F*, about which pinion *C* rotates, is fastened to the hub of the cone-pulley. The pin *M*, which may be clamped in a slot in casting *A*, serves to lock casting *A* and disk *E* together when placed in the upper end of the slot. When the pin is in this upper position, another slot in the disk *E* is engaged by the inner end of the pin. When this pin is lowered into engagement with the

stationary arm D, casting A is held stationary. The speed changes are obtained in the following manner: When the direct drive and the faster range of speeds are required, pin M is moved up so as to lock casting A and disk E together; the shaft and cone-pulley then rotate at the same speed. When the casting A is held stationary and disk E is free to revolve, the motion is transmitted through gears F and C to disk E, and the shaft in this way is rotated at a slower speed. In order to secure this reduction of speed by transmitting the motion through the planetary gearing, pin M is lowered into engagement with arm D, thus locking casting A.

Backing Hammer. A type of sledge hammer used by blacksmiths for the very lightest work for which a sledge hammer would be required; the backing hammer generally has a ball-peen end like a hand hammer.

Backing-Off. See Relieving.

Backlash. The lost motion between two machine parts which transmit motion one to the other is often called backlash. This term is applied to lost motion between gear teeth, between cams and their followers, between screws and nuts and other adjacent parts.

Back Pitch of Riveted Joint. The distance between the center-lines of any two adjacent rows of rivets is sometimes called the "back pitch." This distance, which is measured at right angles to the direction of the joint, should be at least twice the diameter of the rivets for boiler work. Where a single rivet in the inner row comes midway between two rivets in the outer row, the sum of the two diagonal sections of the plate between the inner rivet and the two outer rivets should be at least 20 per cent greater than the section of the plate between the two rivets in the outer row.

Back-Rest. Any support employed in machine tools for supporting revolving work, and specifically applied to rear supports for long, slender shafts or similar work while being turned or ground.

Baily's Metal. Baily's metal is an alloy composed of 82 per cent of copper, 13 per cent of tin, and 5 per cent of zinc, which was used for making the standard imperial yard of Great Britain and the standard yard of the United States in the Bureau of Weights and Measures. It has also been used for making nearly fifty copies of the standard yard supplied by the British government to foreign governments and public institutions.

Bakadie. Alloy steel which, after heat-treatment, has a surface hardness of from 63 to 65 Rockwell, and at the same time, has an unusually tough core. The hardness insures good wearing properties and high resistance to abrasion. Intended especially for use in making molds for producing synthetic plastic parts. Especially suitable for molds in which the impressions are "hobbed."

Bakelite. Phenolic resinoid plastics (commonly designated by the trade name "Bakelite") were invented in 1907 by Dr. L. H. Baekeland. Like most products of creative chemistry, phenol resinoid bears no resemblance to the raw materials from which it is made. Principal among these raw materials are phenol or "carbolic acid," a white crystalline solid, and formaldehyde, a gas, which when dissolved in water is commonly known as formalin. Both are highly reactive substances. Under certain definite, controlled conditions they may be caused to combine chemically, forming a distinctly new and highly useful product, a product which is resin-like but superior in its properties to any natural resin. In its raw, or primary state, phenol resinoid is quickly softened by moderate heat, and is soluble in certain solvents, notably alcohol. Further heating, however, causes it to harden, after which it cannot again be softened at any temperature. Furthermore, the solvents which served to dissolve it in its primary state now have little or no effect on it. This property of being first fusible and soluble, and then, under the influence of heat, becoming infusible and insoluble—of becoming, in fact, a material of pronounced hardness, strength, and resistance to deteriorating agents generally, has made phenol resinoid outstanding among organic plastic materials. It is called a resinoid to distinguish it from natural resinous substances. Bakelite plastics may be classified generally in the following groups:

1. Molding Materials.
2. Coating Materials.
3. Impregnating Materials.
4. Cements.
5. Bonding Resins.
6. Synthetic Resins for Air-Drying Finishes.
7. Cast Resinoids.
8. Resinoid Varnishes for the Production of Laminated Materials.

Molding Materials: These materials are furnished in powder, flake, granular, board and blank form. For compression molding in hardened steel molds under pressure varying from 2,000 to 8,000 lbs. per square inch at temperatures ranging from 270° F., to 350° F., cooling used depending upon type of material. *Thermoplastic* types are also injection molded hot at temperatures ranging from 325° F. to 425° F.—mold temperatures ranging from room temperature to 200° F., depending upon type and material used. Molded materials are used for electrical insulation,

mechanical parts, radio parts, hardware, packages, closures, displays, toys, and novelties. There are many varieties of Bakelite molding materials which have been developed for special conditions of use such as for molded parts which require an unusually high degree of heat, water, or shock resistance, elasticity or brilliant finish and color.

Coating Materials: Varnishes and enamels (baking) are heat-reactive coating materials for electrical coils, windings, armatures and insulation. They are non-hygroscopic, unaffected by extremes of climate, impervious to oils, water, solvents and most chemicals. Effective as insulating coatings because of their dielectric strength, hardness and resistance to heat; also effective as chemical protective coatings for tanks, machinery or any other equipment that may be subjected to erosion or chemical corrosion. They are hardened by baking at temperatures from 170° F. to 300° F. for from several minutes to several hours, depending upon the nature and size of the part being coated.

The lacquers provide hard, transparent coatings for highly finished metal. They are resistant to solvents, gases, water and perspiration. Baked, after application, at 275° F. for twenty minutes. Used for coating metal hardware, precision instruments, vanity cases, belt buckles, mechanical pencils and ornaments.

The calendering materials are special flexible resinoids for coating fabrics or similar materials which are rendered chemical, heat and weather resistant.

Liquid resinoid products are used for impregnation of coils, fabrics or other products to improve their dielectric qualities, chemical resistance, durability and heat resistance. They are used for such purposes as brake lining, armatures, insulating cambric and cable coverings.

Cements: Air drying cements and adhesives are for bonding plywoods and veneers. These adhesives are flexible to rigid in range and have high bonding strength.

Heat hardenable cements provide an extremely hard and tenacious bond which is exceptionally resistant to heat, solvents, and most chemicals. They are employed extensively for cementing together the bulbs and bases of electric lamps and electronic tubes and for bonding wood, porcelain, glass, metal and Bakelite materials. They require baking at 250° F. for several hours.

Bonding Resins: These materials include a variety of resins for either the cold molding or hot molding process. They are used as bonds for abrasive wheels, carbon brushes, phenolic cold molded pieces, resistors, etc. The bonds have good mechanical strength, and are heat resistant and chemical resistant.

Resins for Air-Drying Finishes: Synthetic resins are oil-soluble and oil reactive, quick-drying resins, which have made possible a series of durable paints, varnishes and enamels. They are durable, waterproof, resistant to dilute acids, weak alkalies, solvents, and chemical agents. Finishes made from these resins do not require baking.

Cast Resinoids: These materials are obtainable in a variety of brilliant transparent, translucent, mottled and opaque colors. They can be machined readily, engraved and polished. They are used for costume jewelry, pencils, paper weights, buttons, buckles and many other decorative and industrial applications.

Cast resinoids are readily machined. They are resistant even to the destructive effects of hydrofluoric acid and are used for laboratory equipment such as beakers, graduates and bottles and, also, for electrical insulation. The material is highly non-hygroscopic and has low power-loss characteristics.

These materials are available in transparent, translucent, mottled and opaque effects.

Varnishes for Laminated Materials: Laminated products are fabricated from superimposed layers of paper, canvas, cotton duck, or asbestos fabric impregnated which Bakelite resinoid varnishes and hardened by heat and pressure into a solid, homogeneous state. They are characterized by unusual strength, resiliency and toughness; possess high dielectric strength; exceptional resistance to heat, water, oil and most chemicals. These laminated materials can be machined, punched and polished. They are produced in a variety of sheets, tubes and rods, which are obtainable in special dimensions and sizes. Sheet stock is produced in many solid colors, light shades and the wood-grain and marble simulations. Bakelite laminated is employed extensively for radio and electrical insulation, wall paneling, wainscoting, baseboard trim, table and desk tops, instrument panels, refrigerator breaker strips, silent automotive timing gears, industrial gears and pinions, and roll neck bearings in steel mills.

Bakelite Polystyrene. A thermoplastic molding material that was primarily developed for use as an electrical insulator. Tests made indicate that no noticeable changes occur in the electrical properties of the material with an increase in either temperature or humidity. Tensile strength, from 5000 to 5500 pounds per square inch; impact strength, from 0.14 to 0.16 foot-pound. Since the material was developed primarily as an electrical insulator, it offers marked advantages for use in many electrical products and equipment.

Balanced Slide-Valve. See under Slide-valve.

Balancers. Balancers, also known as "direct-current compensators," consist of a combination of two or more direct-current machines coupled directly to each other, and connected in series across the conductors of a multiple-wire system of electric current distribution. The object of balancers is to maintain the potentials of the intermediate wires of a system, which are connected to the junction points between the machines. When two machines are used, each carries one-half the line voltage; they are then generally employed to provide the neutral of a three-wire lighting system.

Balancing. The rotating parts of many machines must be balanced in order to prevent excessive vibrations, especially if the speed of rotation is high. Balancing may be done either by adding a counterbalancing weight or weights to the rotating part, or by removing metal from the heavy or unbalanced side. In the case of reciprocating steam engines, it is the general practice to add a weight opposite the crank in order to counteract, as far as possible, the unbalancing effect of the crank and its connecting-rod. The weight necessary for counterbalancing is calculated by the engine designer in accordance with the various factors involved, and this balancing weight is usually incorporated in the design of the crank, so that it forms an integral part of it. In the construction of fast-running machinery of various kinds, balancing is often necessary because of slight weight variations at different points around the circumference of such parts as flywheels, cylindrical drums, disks, etc. The balancing of such parts involves locating the unbalanced side and either counterbalancing it or removing the excess weight, in order to prevent excessive vibrations at high speed. The excess weight which causes the lack of balance may be very slight, as the vibrations are due to the action of centrifugal force when this unbalanced mass is rotated rapidly. The effect of such vibration may be to injure the entire mechanism of which the rotary member forms a part, and the product of machinery of the manufacturing type is also injuriously affected in many cases. For instance, if the wheel-spindle of a cylindrical grinding machine is out of running balance, the resulting vibrations will cause chatter marks on the work. The importance of balancing fast revolving parts has also been demonstrated in connection with many other types of machine tools as well as other classes of machinery, and balancing of machine parts on a commercial basis has been made possible by the development of balancing machines.

Static or Standing Balance: If a circular part, such as a cylindrical drum or pulley, were mounted in bearings in which friction was practically eliminated, and with the axle in a hori-

zontal position, it is evident that if one side were even slightly heavier than the other this unbalanced side would be at the bottom or lowest point possible when the drum or pulley came to a state of rest. If this same part were brought to such a state of balance that it would remain standing when turned about its axis to any position, it would be in *standing* or *static* balance; it does not necessarily follow, however, that this part would be in a balanced state when revolving, although if it has a running balance it will also be balanced statically.

Running or Dynamic Balance: If the rotating part is in the form of a thin disk, static balancing, if carefully done, might be accurate enough for high speeds, but if the rotating part is long in proportion to its diameter, and the unbalanced portions are at opposite ends or in different planes, the balancing must be done so as to counteract the centrifugal force of these heavy parts when they are rotating rapidly. This is known as a *running* balance or *dynamic* balancing. Theoretically, to obtain a perfect running balance, the exact position of the heavy sections should be located and the balancing effected either by reducing their weight or by adding counterweights opposite each section and in the same plane at the proper radius; but, if the rotating part is rigidly mounted on a stiff shaft, a running balance that is sufficiently accurate for practical purposes can be obtained by means of comparatively few counterbalancing weights located with reference to the unbalanced parts.

Balancing Machines. Several types of machines have been developed for testing the running or dynamic balance of machine parts. Some balancing machines are designed primarily for wheels, disks and comparatively narrow face parts, whereas others are arranged to test various classes of work, such as crankshafts, rotors of generators and motors, pulleys, spindles, etc. Balancing machines are widely used by motor car manufacturers for testing the crankshafts, by electrical machinery manufacturers, and in various other fields, particularly when rotative speeds are high and the requirements are exacting in regard to vibration.

Balancing machines are designed to indicate unbalance and where corrections are required. The Gisholt "Dynetric" balancing machine supports the part to be balanced, freely or so that it is not restrained at either end. The correction for unbalance is indicated directly at the points where corrections are to be made, and without stopping the machine. It is indicated electrically, no optical or mechanical levers or devices being used. Only two switches are employed to obtain the amount and angular positions of corrections required in both correction planes. The machine measures either static or dynamic unbal-

ance, or the combined effect of both in two arbitrarily selected planes of correction.

A balancing machine which has been developed by the research laboratory of the Westinghouse Electric & Mfg. Co. may be used for balancing rotors "on location"—that is, when already assembled in their respective machines. This portable balancing outfit reduces the number of trial runs to two or three, and simplifies the determination of the exact correction weight position. The work of balancing is reduced to simple meter readings and elementary arithmetic. The equipment is provided with a vibration pick-up that is held against the vibrating body.

The General Electric Co. has developed a portable dynamic balancing instrument capable of measuring the amount and phase angle of unbalance vibration in the bearing pedestals of a rotating machine running in its own or substitute bearings at any speed between approximately 600 and 5000 R.P.M. Being portable, it permits balancing rotating equipment without removing the rotor from the machine. In balancing, a sine-wave alternator spindle is inserted in a lathe center hole in either end of the rotor of the machine to be balanced, and the vibration pick-up is placed against the rotor bearing. The two voltages generated in the sine-wave alternator and vibration velocity unit are applied to the measuring instrument. The amount of vibration and the relative angular position of the high spots are then determined. This measurement is made with the machine in its original condition and also with two trial weights attached. From these measurements, calculations are made to determine the amount and location of the weights to be applied for correcting the unbalance.

Ball Bearing Lubrication. To obtain the full measure of efficiency and service from ball and roller bearing equipment, the kind and quality of the lubricant, as well as the system of applying it, must be adapted to the design of the bearing, the design of the machine, and the operating conditions.

Operating Temperatures: Under ordinary conditions the temperature of a bearing while running will be from 10 to 60 degrees F. above that of the room. If it exceeds 125 degrees F., ordinary greases will frequently prove unsatisfactory. They will tend to soften and flow continuously into the path of the rolling elements, causing a rise in the normal operating temperature due to the increased frictional resistance introduced. This may eventually result in the separation of the oil and soap base, with a complete loss of lubricating qualities. In some cases, greases developed for use at high temperatures may be employed Care should be taken, however, to see that they meet all the requirements for adequate lubrication.

Mineral oil of proper physical and chemical properties is an ideal lubricant for ball and roller bearings when the housing is designed to control the quantity entering the bearing and to prevent leakage and protect the bearing from the entrance of foreign matter. A ball or roller bearing should not be subjected to temperature in excess of 300 degrees F., because of the danger of drawing the temper of the hardened steel races and balls.

Quantity of Lubricant Required: In no case does a ball or roller bearing require a large quantity of lubricant. On the contrary, a few drops of oil, or a corresponding amount of grease, properly distributed over the running surfaces of the bearing, will provide satisfactory lubrication for a considerable period of time. A large volume of lubricant within a bearing will usually result in high operating temperatures, due to the working or churning of the lubricant by the rolling elements and retainer. This may seriously impair the useful life of the lubricant through oxidation or sludging of the oil or actual disintegration of greases.

Use of Grease: If grease is used, the housing should not be kept more than one-fourth to one-half full of the lubricant. Unlike oil, there is no way of controlling with any degree of exactness the quantity of grease in a housing, and greater care must therefore be taken to avoid overloading. A bearing that runs at too high a temperature will often return to normal temperature if some of the lubricating grease is removed.

Grease is being used successfully for the lubrication of ball bearings at high speeds, but great care is necessary, both from the standpoint of housing design and selection of the lubricant, in order to obtain satisfactory results. Any system employed must be designed to feed only a limited amount of grease to the bearing. For the average application at operating speeds up to 3600 revolutions per minute, a grease of soft consistency, such as a No. 2 grease, will usually be found satisfactory, provided it is suitable in other respects. Hard greases, such as No. 3, may be used if the grease is to serve as a packing medium around the shaft to prevent the entrance of dirt, water, or other corrosive substances.

Sealed Bearings: Bearings for certain classes of service must operate over long periods without relubrication, as, for example, a motor installation on an airplane beacon; hence the efforts of ball-bearing manufacturers to produce bearings so completely sealed as to enable them to retain their original charge of grease for many months. In appreciation of this requirement, the petroleum industry has developed lubricants that will maintain lubrication for a long period without change in structure, homogeneity, lubricating properties, or leakage.

Ball Bearings. Ball bearings are designed to provide rolling contact between a rotating shaft or other part, and its supporting members, instead of sliding contact as with plain bearings. Ball bearings are used in preference to sliding bearings principally for the following reasons: There is less loss of power on account of the lower coefficient of friction; the friction of a ball bearing is independent of the viscosity of the lubricant or its temperature; the frictional resistance at starting is very much less than in a sliding bearing; ball bearings are much shorter and more compact than sliding bearings; the scraping and fitting of bearing linings is not necessary; the danger of heated bearings is practically eliminated; a bearing of proper construction can adjust itself to deflections of the shaft; the wear is practically negligible.

Ball bearings may be divided into two main types: *radial* bearings and *thrust* bearings. The former are designed primarily for loads at right angles to the shaft axis, and the latter for axial loads. All radial bearings, however, will withstand thrust loads, and those properly designed for angular contact may resist thrust loads which are equal to or greater than the radial load.

Angle of Contact and Thrust Capacity: Figuring the capacity of a ball bearing under combined loads is complicated as it is a function of the maximum safe ball load, the angles of contact and of load application, as measured from the plane of the balls, and also the center angle between the balls. As the pure thrust capacity of the bearing is increased by enlarging the angle of contact, there is a reduction in pure radial capacity. For example, a bearing having an angle of contact of 10 degrees will carry, as thrust, 77 per cent of its radial capacity, whereas its radial capacity is reduced 1.5 per cent. Again, a bearing having an angle of contact of 30 degrees will carry, as pure thrust, 252 per cent of its radial capacity, and has a loss of 13.4 per cent in radial rating.

Any ball bearing under combined loads becomes an angular contact bearing. This angle of contact can either be incorporated in the design or obtained by deformation of the parts under load. In other words, what is known as an annular bearing becomes an angular contact bearing when thrust is applied. Under pure radial load, the contact between the balls and races is in line with the applied load and at right angles to the shaft, but as soon as thrust load is applied, the contact becomes angular and is caused by motion between the inner and outer races until the material is deformed sufficiently to resist the load.

Percentages of Radial and Thrust Loads: There are three types of bearing that are combined load carriers: First, the annular ball bearing, which is primarily designed for radial loads

and has no angle of contact incorporated in its design, therefore having minimum thrust capacity (approximately 20 per cent of its radial capacity). Second, the one-direction angular contact bearing, which has a thrust capacity depending upon race design and the angle incorporated, which is generally made so that the thrust capacity is 100 per cent of the radial capacity. (This bearing, however, when used for combined loads, can only be used in pairs, and must have a threaded or shim adjustment incorporated in the mounting design to allow for initial adjustment.) Third, the double angular type bearing which is really two of the previously mentioned bearings built as a self-contained unit. The funtioning of this bearing is not dependent on any exterior adjustment, and the angle of contact is generally such that it will sustain approximately 150 per cent of its radial capacity as thrust.

Ball Bearings, Mounting. If the bearing is to carry a radial load without thrust, the inner race should have a light driving fit on the shaft and be securely clamped against a shoulder by a nut or clamping device which is proof against jarring loose. The outer race of a bearing subjected to a radial load only should fit closely in its retaining box or housing, but be free to "float" or shift in an endwise direction. When the outer race is mounted in this way, it will align itself with reference to the inner race and will tend to have a slow intermittent creeping movement, insuring a proper distribution of the load over the entire surface of the outer race.

If there are several radial bearings on the same shaft, the end-thrust in both directions should be taken by the same bearing, and the outer races of the other bearings should be free to locate themselves. It is considered good practice, when two bearings are mounted on one shaft, to prevent axial thrust by making the inner race of each bearing a light driving fit on the shaft. The outer race of one bearing has a sliding fit in its seat and is given a slight amount of axial play (say, from 0.010 to 0.020 inch); the outer race of the other bearing is also made a sliding fit, but is allowed considerable axial play. The first bearing takes the radial load and end-thrust, and the second bearing, a radial load only.

Ball-Broaching. Ball-broaching is a method of securing bushings, gears, or other components without the need for keys, pins, or splines. A series of axial grooves, separated by ridges, is formed in the bore of the workpiece by cold plastic deformation of the metal when a tool, having a row of three rotating balls around its periphery, is pressed through the parts. When the bushing is pressed into a broached bore, the ridges displace

the softer material of the bushing into the grooves—thus securing the assembly. The balls can be made of high-carbon chromium steel or carbide, depending on the hardness of the component.

Ball-Burnishing Process. Burnishing, according to one meaning of the word, consists in finishing the surfaces of work by rubbing with a highly polished steel hand tool, which hardens and polishes the surface metal. The ball-burnishing process produces the same effect, but in an entirely different manner, employing quantities of hardened and polished steel balls which are caused to roll over the work while under pressure. This pressure is effected by the weight of the balls which are confined within a tumbling barrel. Each ball thus acts as an individual burnishing tool, and as it rolls over the work, pressed by the mass of balls and work above, it leaves a burnished path on the work.

To burnish a quantity of work, the work and balls are placed in the barrel, water is then added until the contents of the barrel are covered. In this water, about four ounces of burnishing soap chips have previously been dissolved. The handhole covers are then clamped in place, and the mixture tumbled from one to five hours, depending upon the character of the work, metal, etc. The speed ordinarily employed for tumbling ranges from 10 to 30 revolutions per minute, the usual speed being 15 revolutions per minute. After the work has been burnished sufficiently, it is separated from the balls by dumping the mixture into a screen of sufficiently coarse mesh to allow the balls to drop through.

Instead of steel balls, small round steel punchings that are ordinarily a scrap by-product when holes are punched in steel articles, may be employed in the tumbling barrels. These steel punchings are first tumbled with no work in place, and then, after the corners are well rounded, the work is put into the tumbling barrel. It is claimed that the burnishing effect is almost as good as that obtained when hardened steel balls are used, while the cost of the punchings is almost negligible.

Ball Classification. Ball-bearing balls are graded in four main classes, known as "alloy," and A, B, and C grades. Alloy steel balls have the greatest crushing strength and do not vary in size more than 0.0001 inch. Balls classified as A-grade are made from high-grade tool steel and do not vary over 0.001 inch above or below the exact dimension. Balls known as B-grade are the seconds taken from the two higher grades mentioned, and do not vary more than 0.002 inch above or below the exact dimension. The C grade, commonly known as hardware balls,

are those picked from the higher grades when these show a defective surface. They may or may not be as accurate as to size as the other grades, according to the use to which they are to be put.

Ballizing. Ballizing is a specialized form of burnishing or sizing and finishing bores. Usually, a carbide ball having a predetermined interference fit is pressed through the hole to be burnished. The balls are generally made 0.0005 to 0.002 inch per inch of diameter larger than the upper limit of the hole diameter to be finished. As the ball is forced through the hole, the wall is expanded. After the ball has passed, the wall springs back slightly, but a portion of the deformation is permanent.

Band Saw. The metal cutting band saw uses a continuous ribbon-like steel loop with hundreds of cutting teeth on one edge. The loop or band is carried on the rims of two or sometimes three wheels, one of which is powered to provide the drive. Friction between the band and the wheel prevents slippage. The distance between the wheels can be varied mechanically or hydraulically to permit adjusting the tension on the band. This tension, plus the guides for the band, give the ribbon-like tool a rigidity as great as that of much heavier tools.

There are two basic types. One type is "vertical" and has one wheel located above the other with a horizontal work table through which the band passes. This type is used for contour sawing, notching, slotting, serrating, splitting, and for some cut-off work. The other type is the so-called "horizontal" type in which both wheels are located in the same horizontal plane. This machine is used primarily for cut-off work, wheels being mounted on a movable frame which descends on the stock to be cut.

The particular virtue of the band saw is that the blade is constantly moving in a direction to accomplish work; that is, it is always cutting. Furthermore, all of the teeth in a blade are utilized because every tooth must pass through the work and rapid cutting can be achieved.

The vertical or contour machine is particularly popular because it can cut shapes directly from the stock without having to reduce the unwanted material to chips. Cuts can be made directly to the lay-out line so little if any additional machining is required. Fixturing is simple because the perpendicular cutting force holds the work down against the table. In fact, fixturing can consist of simply the operator's hand or a backstop and side guides, or a mandrel. This simple fixturing is used primarily on machines that have tables with hydraulic power feed. The tables move the work into the blade so the operation

becomes semi-automatic. Some of the hydraulically operated machines also have such features as hydraulic safety brakes in case of band breakage, hydraulic control of variable speeds from 40 to 15,000 surface feet per minute, hydraulic control of the guide post height for the blade, and hydraulic blade tensioning.

These semi-automatic machines find their greatest use in performing operations on duplicate parts which were formerly machined on other machine tools. The contour saw can also perform internal cutting of shapes. To do this, a hole is drilled through the work big enough to admit the blade. The blade is then broken, threaded through the hole, and the broken pieces joined by welding with a small resistance welder attached to the side of thc machine. The small bump caused by welding is then removed by a tiny grinding wheel. After the cut is completed the saw is again broken to remove the work. For compound angles, the table can be tilted.

The semi-automatic machines will handle many other types of blades in addition to saw blades, permitting them to grind with a "fine grind band," file with a file band, polish with a polishing band, slice with a knife or scalloped-edge band, and even cut such material as glass or granite with a diamond band.

Early bands were made of carbon steel because high-speed steel metallurgy had not been able to overcome the brittleness which caused high-speed steel bands to fracture when they flexed over the wheel. Now, however, the problem has been overcome and high-speed steel bands are available to give longer life and higher cutting speeds.

Friction sawing can also be performed on a band saw using a special band with so-called raker teeth. These serve merely to brush away the metal heated almost to melting by the frictional heat developed. The blade is not damaged by the heat because the teeth make only momentary contact and have plenty of time to cool while traveling around before they again make contact.

The horizontal band saw cut-off machine has become increasingly popular with the advent of the high-speed steel band which permits it to match the conventional power hacksaw in speed of cutting off the tougher alloy steels.

The machine usually has a flat bed on which the stock is placed and is equipped with vises and clamps to hold the work. The saw head which contains the wheels and band descends on the work and its feed rate is automatically controlled to a preset pressure regardless of the varying cross-section of the material. This latter feature is particularly important when cutting heavy tubular or structural sections. Some machines are also equipped with automatic indexing for moving the stock automatically the desired amount after each cut.

Barff Process. A method for producing a magnetic oxide on iron or steel, in order to protect it from the corrosive effects of air and moisture. See Bower-Barff Process.

Barium. Barium is one of the metallic chemical elements, the chemical symbol of which is Ba. Its atomic weight is 137.4. The specific gravity of barium is 3.75; its melting point, 850 degrees C. (1562 degrees F.); and its electric conductivity (silver = 100), 30.61. Barium, as a metal, is expensive. The various salts formed by barium, however, are inexpensive. It occurs chiefly in the form of barytes, or heavy spar, and witherite. It is a metal difficult to obtain in pure form. The metal possesses a silver-white luster, but is very easily oxidized on exposure. It is slightly harder than lead. One of the most important uses is in the barium salts, which are frequently used for heating baths for metals to be hardened. Barium chloride ($BaCl_2 + 2\ H_2O$) is especially valuable for this purpose.

Barium Carbonate. A carburizing material used in combination with wood charcoal for increasing the carbon content of the surface of low-carbon steel, so that the steel may be case-hardened. A carburizing mixture contains 40 to 60 per cent, by weight, of barium carbonate, the remainder being wood charcoal.

Barium-Chloride Heating Baths. High-speed steel requires to be heated to a much higher temperature for hardening than does ordinaryy carbon steel. While a heat of from 1400 to 1600 degrees F. is sufficient for tools made from carbon steel, a heat of from, at least, 1800 to 2200 degrees F. is required in order to satisfactorily harden high-speed steel tools. The ordinary lead bath commonly used for heating carbon steel tools cannot be used at such high temperatures as these, and as it is, in general, unsatisfactory to heat the tools in an oven furnace, owing to the difficulty of correctly determining the hardening temperature when the tools are heated in this way, some heating medium has been sought which could stand high temperatures and in which the pieces to be hardened could be immersed so as to obtain a uniform heat without danger of burning delicate points or cutting edges—a danger which is always present when high-speed steel tools are heated to a high temperature in an open heating furnace. A temperature up to 2200 degrees F., and even higher, can be obtained by the barium-chloride bath.

The hardening of high-speed steel in barium-chloride electrically heated baths has not always been satisfactory. In one series of experiments the results were good when the salt bath was new, but it appeared that the chemical composition of the salt bath in the electric furnace gradually changed, producing a

soft surface on the steel which was quite noticeable when the salt bath had been in use for about a week. This softness of the surface was noticeable directly after the hardening, and not merely after the temper had been drawn. A certain sediment collected in the electric salt bath, and the color of the barium chloride became darker. The same barium chloride melted in an ordinary graphite crucible retained its lighter color and, even after two full weeks' use, the hardening results were satisfactory. The amount of barium chloride used in the electric furnace was much greater than that required for doing the same amount of work in a graphite crucible.

Experiments made later in Sweden indicate that it is possible to obtain perfectly satisfactory results by hardening high-speed steel in electric barium-chloride baths. If silica brick or clay is used for the crucible, it will be found that there is no chemical action and that high-speed steel can be hardened without any soft spots on the surface. The risk of breakages in hardening also appears to be diminished, when there are no soft spots on the surface. The objectionable results, therefore, in the early experiments are almost certain to have been due to the character of the lining of the crucible and the chemical action of the electrically heated salt bath on this lining. When the proper kind of crucible is used, it appears that properly conducted hardening of high-speed steel in electrically heated salt baths cannot be surpassed by any other hardening method, as regards either the accuracy with which the temperature can be obtained and maintained, the hardness of the surface, or the freedom from hardening cracks.

Barium Chromate. A material used in paints for protecting iron and steel against corrosion; it is pale yellow in color and made by treating barium chloride with sodium chromate. On account of the impurities generally contained, its protective value is not very high.

Barium Sulphate. A material found in large quantities in nature, extensively used in paints for the protection of iron and steel against corrosion. It grinds in 10 per cent of oil. An artificial form known as *blanc fixe* may be made by precipitating a barium salt by a soluble sulphate. Both the natural and artificial product may contain acids, and should be tested for this before being used as a protective paint.

Barlow's Formula. One of the most commonly used formulas for calculating the strength of cylinders subjected to internal pressure is known as the *Barlow formula,* and is as follows:

$$t = \frac{DP}{2S},$$

in which $t =$ thickness in inches; $D =$ outside diameter in inches; $P =$ pressure in pounds per square inch; $S =$ allowable tensile stress in pounds per square inch.

Barograph. A form of *barometer* for measuring the pressure of the atmosphere, which does not employ mercury or other liquids as does the ordinary barometer. Other forms of a barometer of this class are aneroids and baroscopes.

Barometer. The barometer is an instrument for measuring the pressure of the atmosphere. In its simplest form it consists of a tube about 36 inches long, hermetically closed and having a vacuum at the upper end, and containing mercury. Two types of this form of barometer are made. In the *cistern* barometer, the tube is placed with its open lower end in a vessel containing mercury, the pressure of the atmosphere being measured by the difference of the height of the mercury in the tube and in the cistern. In the *siphon* barometer, the tube is bent at its lower end into a U-shape. The pressure of the atmosphere is read off as the difference of the levels of the mercury in the two vertical tubes of the U. Various forms of barometers which do not employ mercury or other liquids are also made, known as *aneroids, baroscopes, barographs,* etc. Normal atmospheric pressure is assumed to exist when the difference between the two levels of mercury in the barometer is 29.92 inches (760 millimeters).

Barometric Aerometer. An instrument for ascertaining the specific gravity of liquids, consisting of a vertical U-tube, with open ends, mounted upon a stand. The method in which it is used is as follows: Water is poured into one branch of the tube and the oil or liquid the specific gravity of which is to be measured is poured into the other. The vertical parts of the tube are provided with graduations and the relative height of the water in the one leg of the U, and the liquid in the other, indicates the specific gravity. See Aerometer.

Barometric Condenser. A barometric condenser which is also known as siphon condenser, is a device for condensing the exhaust steam from engines or turbines, by mixing the exhaust steam directly with the condensing water. This type of condenser is well adapted to plants in which the condensing water is suitable for being fed directly to the boilers and also for plants where only the condensation of the steam is desired and where the water of condensation is not used again.

Baroscope. A form of *barometer* for measuring the pressure of the atmosphere, which does not employ mercury or other liquids as does the ordinary barometer.

Barrel Converter. A converter similar to a Bessemer converter, used in the refining of copper by the *Manhes process.*

Baryte. A barium sulphate used in paints for protecting iron and steel against corrosion; see Barium Sulphate.

Barytes Cement. An acid-proof cementing material composed of pure, finely ground sulphate of barium made into a putty with a solution of silicate of soda. This solution sets very hard when heated and is then proof against acids. The specific gravity of the silicate of soda should be between 1.2 and 1.4, or from 24 to 42 degrees Baume; if too thin, the cement will not hold; if too thick, it will expand and break.

Basaloy. Non-shrinking, non-expanding metal alloy with a melting point of 255 degrees F. Suitable for making small master patterns. Since the alloy is non-shrinking, there is no difference in size between the original and the base-alloy pattern.

Base in Chemistry. A chemical base is a compound which will react with acids to form salts. It generally consists of a combination of a metal with oxygen. All bases that dissolve in water are known as *alkalies*.

Base Circle of a Gear. There are various curves which might be applied to gear teeth in order to secure rotation between two gears having intermeshing teeth, but the involute curve is used almost universally because it has certain practical advantages. If a circular disk were placed upon a drawing-board, an involute curve would be described by the end of a taut line when the latter was unwound from this disk. The disk represents what is known as the *base circle*, because it is from this circle that the involute is derived. The base circle must always be smaller than the pitch circle, in order to obtain involute tooth curves which meet practical requirements. A tooth curve cannot extend below the base circle from which it is derived.

The ratio of gearing depends upon the diameters of the pitch circles, the sizes of which are proportional to the numbers of teeth in the pinion and gear. The base circles must also be proportioned according to the same ratio. For example, if the *pitch diameter* of a gear is four times that of the pinion, the base circle of the gear must also be four times as large as that of the pinion base circle. The diameters of these base circles may be changed, but they must always remain proportional to the velocity ratio the same as the pitch circle diameters.

Base Circle Radius. To find the base circle radius, multiply the pitch circle radius by the cosine of the pressure angle.

For example, if a gear has 20 teeth of 1 diametral pitch and a pressure angle of 14½ degrees, the pitch radius = 10 inches. Then

$$\text{Base circle radius} = 10 \times 0.96815 = 9.6815 \text{ inches.}$$

Base Pitch of Gear. See Normal Pitch.

Basic Bessemer Process. See Bessemer Process.

Basic Dimension. The basic size of a screw thread or machine part is the theoretical or nominal standard size from which variations are made, as in the case of fitted parts which must have an allowance for providing a certain class of fit. The use of the hole diameter as the basic diameter has practical advantages in obtaining different classes of fits, especially when it is economical to finish holes by means of standard tools. For example, assume that holes are to be finished by reaming, and that shafts or plugs are to be fitted into them, this being a common condition in connection with various machine-building operations. If the diameter of the hole is basic, its size, within a small tolerance, may be maintained readily by the use of proper reaming equipment, and the diameter of a shaft or plug may be varied much more readily than that of the hole, in order to obtain the allowance for whatever class of fit is desired; therefore, different kinds of fits in holes finished by the same reamer may be obtained merely by grinding the shaft or plug to a diameter which gives the proper fit allowance. In the case of threaded holes, the tap is usually solid or non-adjustable, whereas dies ordinarily may be adjusted readily to obtain different classes of fits.

As both the hole and shaft or plug would ordinarily be given a certain tolerance, the basic dimension of a hole (except for forced fits) should be the minimum limit or diameter, there being a plus tolerance, and the nominal dimension of a shaft or plug should represent the maximum limit or diameter, there being a minus tolerance. The advantage of this method is that the minimum clearance between hole and shaft, or the "danger zone," is indicated by a direct comparison of the basic hole diameter and the nominal shaft diameter; the direction of the tolerances is such as to increase this clearance. For a forced fit, the basic hole size is the maximum diameter, the tolerance being minus, and the nominal shaft size is the minimum diameter, the tolerance being plus; consequently, the minimum fit allowance or interference between hole and shaft (or the "danger zone" for a forced fit) is indicated by a comparison of the basic hole diameter and the nominal shaft diameter. In this case the direction of the tolerances increases the interference or forced fit allowance.

When it is economical to use cold-drawn or other commercial stock without machining then the maximum shaft size should be basic.

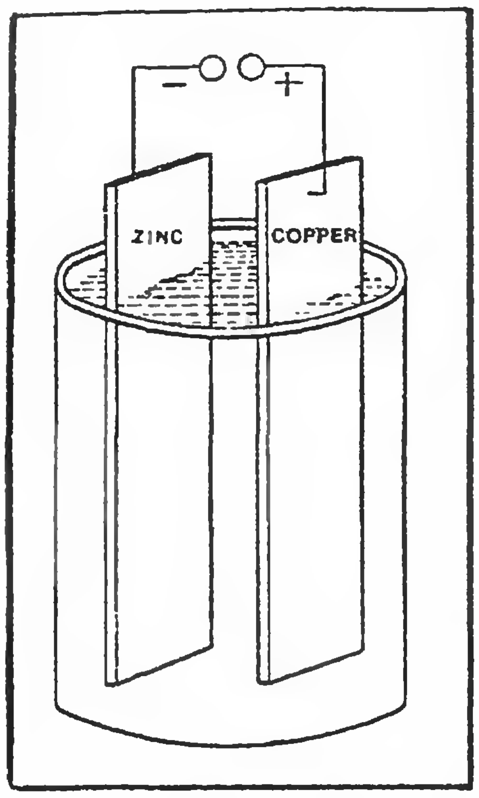
Basic Firebrick. A firebrick in which alumina predominates.

Basic Pig Iron. A term applied to pig iron containing so ittle silicon and sulphur that it is suited for easy conversion

into steel by the basic open-hearth process (restricted to pig iron containing not more than 1.00 per cent of silicon).

Basic Salt. In chemistry, a basic salt is formed when all the hydrogen has been removed from an acid and yet some of the base remains.

Batteries. The apparatus for transforming chemical energy into electric energy is known as a *primary cell.* Two or more of these cells joined together form a *primary battery,* although the term "battery" is frequently applied to the single cell as well. A primary cell consists of a liquid, known as the *electrolyte,* and two metals called the *elements* or *electrodes.* The action of the primary cell depends on the decomposition of the electrolyte, and the effect of the parts of the liquid on the electrodes. That electrode on which the electrolyte acts the more vigorously is termed the *positive,* or *anode,* and is indicated, by a + sign, since the current is flowing away from it into the electrolyte: the other is termed the *negative,* or *cathode,* and is indicated by a — sign, since the current is flowing into it from the electrolyte. But the current flows out into the wire from the pole or terminal joined to the negative electrode and, hence, that terminal is called positive; while the negative pole of the cell, joined to the positive electrode, is so called because the current is flowing into it from the wire.



Simple Voltaic Battery

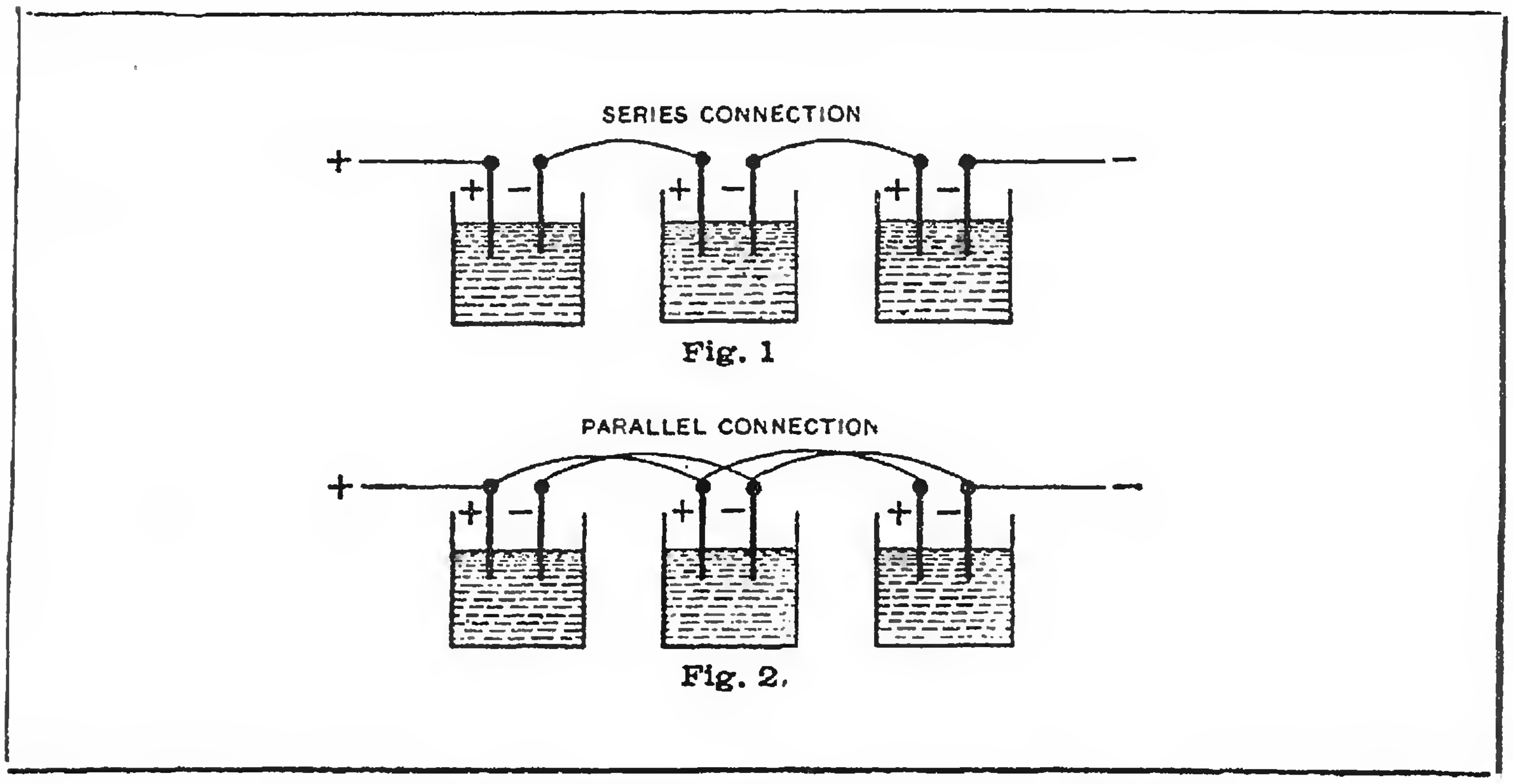
In the simple voltaic cell, shown in the illustration, dilute sulphuric acid (H_2SO_4) is used as the electrolyte, and copper and zinc strips as the electrodes. When these electrodes are connected externally, the radical SO_4 of the sulphuric acid, which has a greater affinity for zinc than for copper, combines with the zinc, and the hydrogen appears at the copper electrode, and an electric current will flow through the conductor and the cell. A similar action occurs in all other cells, but the radical liberated depends on the electrolyte and the electrodes used.

In *dry cells,* which now constitute over 90 per cent of the primary batteries in use, the electrolyte, instead of being in liquid form, is carried by some absorbent material or combined with some gelatinous substance, so that, no matter in what position the cell may be put, the electrolyte will not be spilled. Various sizes ranging from AAA, which is ½ inch in diameter and 1 inch long, to the No. 6, which is 2½ inches in diameter

and 6 inches long, are used singly and in packaged combinations wherever a dependable and easily transported source of electric power is required.

Cells are connected in series when the anode of one cell is connected to the cathode of another (Fig. 1). The combined internal resistance will be increased, and is equal to the resistance of one cell multiplied by the total number. The electromotive force of the battery will be that of one cell multiplied by the number of cells. Large combinations of dry cells forming batteries with voltages ranging up to 100 volts or more are available for special applications.

Cells are *connected in parallel* when all the anodes of a battery are connected (Fig. 2) and all the cathodes are connected to-



Batteries Connected in Series and in Parallel

gether; the result is the same as if the battery were a single cell having elements of the same area as that of the combined anodes and the combined cathodes. As the resistance of a cell varies inversely as the area of the electrodes, the resistance of the battery will be that of one cell divided by the number of cells, but the electromotive force will not be increased. See also Storage Batteries.

Battery Reading. The condition of storage battery cells during charging or discharging, may be determined either by the specific gravity method, using a hydrometer, or by the voltage method in which the voltage of the cells is determined. The specific gravity method is superior to the voltage method, as the voltages denoting various conditions of the cell vary with the current as well as with the temperature, age, and condition of the plates.

Baume Hydrometer. The Baume hydrometer is an instrument used for determining the specific gravity of liquids. It consists of a glass tube with a bulb at one end, containing air, and having a weight at the bottom, so that it will float in an upright position in the liquid, the density of which is to be measured. The depth to which the instrument sinks in the liquid is read off on a graduated scale which indicates the specific gravity.

Bauxite. Bauxite is a soft clay-like substance, and, chemically, is the purest naturally occurring amorphous oxide of aluminum known. It contains large percentages of alumina (from 33 to 77 per cent), the chief value of which is that it is the main source of metallic aluminum. The material is first purified by chemical processes, after which the aluminum hydroxide is reduced in the electric furnace. Besides its use in the aluminum industry, it is used for the manufacture of artificial abrasives, firebrick and crucibles because of the refractory qualities of alumina. This mineral was originally found at Baux, France, from which it derives its name. Bauxite is mined in the southern part of the United States, in the states of Arkansas, Georgia and Alabama. However, the amount of bauxite mined in the United States is less than 15 per cent of the entire world's output. Other important mining areas are the European countries of Hungary, Italy, and France and throughout the rest of the world in such places as the Guianas, Brazil, and Indonesia.

Bayer Process. The Bayer Process is a method of producing pure alumina from bauxite. In this process, aluminate of soda ($Na_2Al_2O_4$) is formed by dissolving the alumina in the bauxite directly in a caustic-soda solution. The bauxite is first ground to about ¼-inch size pieces, then calcined or roasted to drive off the water, and after the calcined material has cooled, it is finely ground and then introduced into a 40 per cent caustic-soda solution contained in a large vessel. Steam is let into a jacket around the vessel for heating the solution, and the operation is continued for about three or four hours. About 96 per cent of the alumina content of the bauxite can be extracted in this way. The solution is filtered and afterward passed into another cylindrical vessel through which passes a shaft with paddles for stirring the liquid. In this vessel, the solution is heated for about 36 hours, at which time about 70 per cent of the alumina in solution will precipitate as hydroxide ($Al(OH)_3$). A small amount of hydroxide is usually added to the solution at the beginning of the process of precipitation, in order to start the reaction. The solution carrying the precipitated hydroxide is filtered under pressure. The filter cakes are dried in the air, calcined to drive off the remaining moisture and convert the hydroxide into oxide, and, in that way, practically pure alumina is produced.

Beam Compasses. Beam compasses, which are intended for drawing large circles or arcs, consist of a beam or strip of hard wood, carrying two heads with provision for holding a needle point and pencil-holder or pen. The head carrying the needle point is usually clamped at one end of the beam or bar, while the one carrying the pencil-holder or pen is adjusted at any point along the beam that may be required for the radius of the arc or circle to be drawn.

Beams. Parts of machines and structures subjected to bending are known mechanically as *beams;* hence, in this sense, a lever fixed at one end and subjected to a force at its other end, a rod supported at both ends and subjected to a load at its center, or the overhanging arm of a jib crane, would all be known as beams.

The stresses in a beam are principally tension and compression stresses. If a beam is supported at the ends and a load rests upon the upper side, the lower fibres will be stretched by the bending action and will be subjected to a tensile stress, while the upper fibres will be compressed and be subjected to a compressive stress. In addition to the tension and compression stresses, a loaded beam is also subjected to a stress which tends to shear it. In most cases, the shearing action can be ignored for metal beams, especially if the beams are long and the loads far from the supports. If the beams are very short and the load quite close to a support, then the shearing stress may become equal to or greater than the tension or compression stresses in the beam and in that case the beam should be calculated for shear.

Beam Formulas: In the practical application of beam formulas, there are two general classes of problems: (1) To determine the maximum safe load a given beam will support; (2) to determine the size of beam to support safely a given load. The maximum safe load for a beam of given size, shape, and material depends upon whether the load is applied at one point or along the entire span; whether the beam is supported at both ends or one end only; and also whether a beam supported at each end is held rigidly or merely rests upon the supports.

To Find Maximum Safe Load: Assume that a standard 6-inch I-beam weighing 12.5 pounds per foot rests upon supports located 8 feet 6 inches apart. This beam supports a trolley and chain hoist. Determine the maximum safe load when the trolley is midway between the supports.

A table of I-beam properties (see MACHINERY'S HANDBOOK) shows a section modulus of 7.3 for this I-beam when in its normal position.

$$\text{Stress } (s) \text{ at center} = \frac{Wl}{4Z} \text{ and } W = \frac{4Zs}{l}$$

in which s = maximum fibre stress; W = load in pounds; Z = section modulus; and l = length between supports in inches. If the safe stress s is 15,000 pounds per square inch (about one-fourth the ultimate strength of structural steel), then, in this example,

$$W = \frac{4 \times 7.3 \times 15{,}000}{102} = 4300 \text{ lbs.}$$

To Find Size of Beam: If the problem is to find the size of beam for supporting a load of 4300 lbs. (see preceding example), then the formula for determining the stress at the center is transposed to find the value of Z.

$$Z = \frac{Wl}{4s} = \frac{4300 \times 102}{4 \times 15{,}000} = 7.3$$

A table giving the section modulus of each I-beam size shows that a 6-inch I-beam weighing 12.5 lbs. per foot has a section modulus of 7.3; hence, the 6-inch size could be used.

When Beam is Fixed at Both Ends: If the 6-inch I-beam previously referred to is rigidly held or riveted at the ends instead of merely resting upon its supports, to what extent will its load capacity be increased? In this case

$$W = \frac{8Zs}{l} = \frac{8 \times 7.3 \times 15{,}000}{102} = 8600 \text{ lbs.}$$

It will be noted that the load capacity is doubled by rigid fastenings at the ends of the beam.

Beam Uniformly Loaded: A wooden beam of southern yellow pine will withstand safely a bending stress of 1300 lbs. per square inch. The length of the span is 10 feet, making l = 120 inches. Assume that the beam width b = 3 inches and the height d = 9 inches. Find the total allowable load, assuming that the load is uniformly distributed along span. For a uniform load

$$W = \frac{8Zs}{l}$$

The section modulus $Z = \dfrac{b \times d^2}{6} = \dfrac{3 \times 9^2}{6} = 40.5$

hence,

$$W = \frac{8 \times 40.5 \times 1300}{120} = 3500 \text{ lbs.}$$

Bearing Metals. The developments which have been made in the design of plain or sleeve bearings include notable improvements in the characteristics of bearing materials. These develop-

ments in the bearing alloys are not restricted to mere changes in composition but include improvements in the physical properties due to refinement in manufacture and proper application of the alloys to shells or housings. Bearing metals are usually composed of alloys of copper, lead, tin, antimony and zinc, and are known as babbitt metal, white metal, brass, phosphor-bronze, and by various trade names. The price of these bearing metals depends largely upon the constituents. Lead and zinc are cheapest, with antimony, copper, and tin increasing progressively in price in the order named, tin being the most expensive. The more lead is used in a bearing, the cheaper it will be. Lead, however, is too soft to be used alone and must be alloyed with one of the other metals. Antimony added to lead increases the hardness and brittleness; with tin added, a tougher alloy is obtained. Nearly all the various babbitt metals are alloys of lead, tin and antimony. (See Babbitt Metal.)

Bronze Bearing Metals: Plain or sleeve-type bearings made of some composition designated as "bronze" are used on many different classes of machines. The S.A.E. composition No. 64 has been widely used. This is known as phosphor bronze. It has good anti-friction qualities and stands up very well under heavy loads and severe usage. S.A.E. standard No. 660 is another alloy which has been widely used. In the automotive industry it is used for such parts as spring bushings, torque tube bushings, steering-knuckle bushings, piston-pin bushings, thrust washers, etc. S.A.E. specification No. 67 is known as a semi-plastic bronze. This is intended for use where a soft bronze with good anti-friction qualities is desired. The plasticity is of especial value when the shaft is soft and the speed high. S.A.E. alloy No. 63 is particularly adapted to bushings subject to heavy loads and severe working conditions or when there is vibration or shock. A hardened steel shaft should be used with this composition.

Porous Bronze Bearings: Bearings of this type are of bronze, but are not cast in the usual way. They are composite bearings, formed initially under heavy pressure from powdered metals and graphite. The pressed composition is subjected to a temperature high enough to convert it into a true alloy resembling cast bronze, but much more porous. This porous structure forms a reservoir for oil.

Laminated Sleeve Bearings: This thin-shell type of bearing consists of either a tin- or lead-base white metal or babbitt fused to a reinforcing back made either of steel or bronze. The steel or bronze shell provides the necessary strength. This type of bearing is used extensively in the automotive industry for connecting rods, crankshaft main bearings, camshafts, piston-pins, etc. These thin-shell bearings are not only low in cost, but efficient and per-

mit the use of a housing of smaller diameter, thus saving in material and making the assembly lighter. Moreover, these bearings are inexpensive to replace. They are used on automobile engines, aircraft engines, and for certain applications in the electrical industry. The characteristics of both the backing material and the lining may, of course, be selected to suit operating conditions. The strength of the backing material is combined with the plastic qualities of the babbitt or white-metal lining, and the degree of plasticity may be varied to suit resistance to pounding or wear. For thin linings, such as are used in aircraft engines, the S.A.E. standard babbitt composition No. 10 may be used with bronze-backed bearings, as it is very fluid. The No. 10 composition contains in percentage: Tin, 90 min.; antimony, 4 to 5; copper, 4 to 5 max.; iron, 0.08 max.; arsenic, 0.10 max.; bismuth, 0.08 max.; lead, 0.35 max.; but the lead content may be as high as 0.60 in finished steel and bronze-backed bearings if a lead-tin solder has been used in bonding the bearing metal to the backing. Bronze as a backing material is preferable to steel for certain applications. Bronze is more economical, excepting where there is large production. If there are thrust loads, the flanges of the bronze backing can carry such loads without lamination or lining. The heat conductivity of bronze is higher than that of steel. Steel, however, is preferable for bearings subjected to heavy duty as in airplane engines, steam turbines, Diesel engines, etc.

Bronze Backing Composition: The S.A.E. standard bronze backing for lined bearings contains, in percentage: Copper, 83 to 86; tin, 4½ to 6; lead, 8 to 10; zinc, 2 max.; other impurities, 0.25 max.

Bearingizing. Bearingizing is a method of burnishing and sizing internal or external surfaces by the rapid peening action of a cam-operated multiple-roller tool. The rotating Bearingizing tool is fed quickly through or over the workpiece, using light pressure. The operation is completed in one pass. Metal is not removed but is compressed by the peening rollers.

Bearings, Anti-Friction. See Anti-Friction Bearings.

Bearings, Knife-Edge. See Knife-edge Bearings.

Bearings, Oilless. See Oilless Bearings.

Bearings, Plain or Sleeve Type. In designing important main bearings, it is essential to obtain the proper relationship between the revolutions per minute, the load on the bearing and the viscosity of the lubricant. In designing a plain or sleeve bearing for a given velocity and load, the aim is to use the highest

unit pressure and oil of the lowest viscosity consistent with safe operation, assuming oil-film lubrication. If the bearing area is based upon the maximum safe unit pressure, then excessive area and unnecessary friction losses will be avoided. General formulas and data applicable to the design of all classes of plain bearings cannot be given because of the many variable factors influencing the design. These factors include the lubricant and method of applying it to the bearing, heat-radiating capacity of the bearing, finish of journal surface, properties of bearing materials, clearance, and other factors.

Critical Pressure: For a given allowable load, a certain velocity and heat-radiating capacity is necessary to maintain an oil film that will support the load. Simple empirical formulas are sometimes used to determine the "critical" or maximum pressure, but the results can only be approximate. According to one formula, the critical pressure in pounds per square inch of projected area, *below* which a perfect oil film may be maintained at a given velocity, and when using the more common grades of mineral engine oils, is approximately as follows: To find the critical pressure, divide the rubbing velocity in feet per minute by the allowable temperature, and multiply the cube root of the quotient by 140. The temperature is assumed to be 140 degrees (200 degrees max. at rubbing surface minus 60 degrees) for the more common grades of mineral engine oils.

Formula for Pressure and Velocity: In the formula $PV = R \div \mu$, if the value equivalent to $R \div \mu$ is determined for a given class of bearings, we have an approximate formula for checking allowable combinations of pressure and velocity for similar bearings and operating conditions; thus, PV is assumed to equal a constant. This constant, for a given bearing, may be determined for an allowable range of combined pressure-velocity values, without knowing what values of R and μ it represents. The value of μ covers a wide range, especially if imperfectly lubricated bearings are included; hence, the constant should be based upon the actual operation of a given type of bearing. The formula PV = constant is quite generally used by manufacturers, but the constants for different types of bearings may vary from 10,000 to 350,000 or higher.

Ratio of Viscosity and Speed to Unit Pressure: If Z equals the absolute viscosity of a lubricant expressed in centipoises; N equals revolutions per minute, and P equals pressure in pounds per square inch of projected area, then the value of $ZN \div P$ for a given design of bearing and lubricant, may be used as a guide in designing similar types of bearings assuming film lubrication. To illustrate, these $ZN \div P$ values might range from, say, 10 to 100 or more, thus indicating that the $ZN \div P$ value might lie

anywhere within this range provided it was far enough from the value representing the breakdown of the oil film to provide a suitable factor of safety. Close to this film-breaking-point value is the zone of minimum friction or of thin-film lubrication; hence, the $ZN \div P$ value upon which the design is based should be as close to the danger zone and to this thin-film and low-friction value as is consistent with conditions. The coefficient of friction is assumed to be a function of these three factors when they are combined to form a single variable $ZN \div P$.

The range of $ZN \div P$ values, or the ideal one for a given bearing, can only be determined by actual tests (by combining maximum speeds with minimum loads and vice versa) because the allowable unit pressure for a given velocity and lubricant depends upon so many variable factors; moreover, these values for a given bearing in the zone representing the dividing line between stable and unstable lubrication, may change considerably as the bearing surfaces are worn smooth by running in. For example, tests on a bronze bearing resulted in a $ZN \div P$ value of 55 at the point of minimum friction or danger zone and a reduction in this value to about 5 after 75 hours running.

As the value of $ZN \div P$ decreases, the coefficient of friction decreases until the oil film begins to break down; then the frictional resistance increases as the contact with the journal is transferred from the oil film to the bearing material, the rate of increase depending upon the extent to which lubricant may remain and the frictional resistance of the bearing material itself. It is evident, then, that frictional losses are lowest when the $ZN \div P$ value is close to the value representing a change from stable to unstable lubrication.

Effect of Speed Upon Allowable Pressure: When a lubricated journal revolves, some of the lubricant will be drawn into the loaded area between the journal and bearing, thus forming a wedge-shaped oil film. This oil film will support the load on the journal within certain limits. If the velocity reaches a point where the heat is not dissipated at fast as it is generated, the viscosity of the oil may be insufficient to carry the load on the bearing; hence the maximum allowable bearing pressure per square inch depends not only upon the velocity, but also upon the viscosity of the lubricant and the rate at which heat is dissipated from the bearings either through ordinary radiation or by artificial cooling. It has been common practice to design many high-speed bearings for comparatively low unit bearing pressures; but if such bearings are rigid, have smooth accurate surfaces, and the right amount of clearance, the unit pressure (assuming perfect lubrication is maintained) may be increased as the velocity increases, up to a maximum pressure which depends

upon such a complicated relationship between a number of variable factors that it can only be determined by tests with a given bearing and lubricant.

Bearing Temperatures: As a general rule, bearing temperatures should not exceed 140 to 160 degrees F. When the temperature exceeds 160 degrees F., a careful study should be made of the mechanical and lubricating conditions of the bearing. According to the practice of the General Electric Co., bearing temperatures ordinarily are limited to 40° C. rise (104° F.) and on large machines to 30° C. rise (86° F.) When the bearing diameter or speed reaches a point at which, with air cooling, the temperatures would exceed these values, water cooling is adopted, the cooling coils usually being embedded in the babbitt. In measuring temperatures, place the thermometer in the lubricating oil if possible.

Bearing Clearance: The ratio of the clearance C (difference between journal and bearing diameters) to the diameter D is very important in connection with bearing lubrication. Accurately machined bearings with ground journals for use in steam turbines, generators, etc., usually have a clearance C equal to the amount obtained by the following formula:

$$C = D \times 0.001$$

Clearances equal to $D \times 0.0015$ and up to about $0.0035\,D$ are often used. If it is necessary to estimate the probable journal expansion, the following coefficients of expansion can be used in the absence of more specific data from the manufacturer of the material employed: Nickel steel (10 per cent nickel), 0.0000073 inch; Bessemer rolled hard steel, 0.0000056 inch; Bessemer rolled soft steel, 0.0000063 inch.

The foregoing values represent the coefficients of expansion per inch of diameter per degree F.

Diameter of Journal: It has been assumed quite generally that the journal diameter should be held down to the minimum required for strength and stiffness in order to obtain as low a rubbing velocity V in feet per minute as possible. It has also been assumed that unit pressure P should be decreased as the velocity is increased; however, it has been demonstrated in modern practice that increasing the velocity makes it possible to increase the unit pressure on well-lubricated bearings of good design and workmanship and within limits varying for different bearings. Moreover, higher unit pressure permits reducing the bearing length in proportion to the diameter, thus avoiding deflections which, in relatively long bearings, make it much more difficult to maintain a uniform and correct amount of clearance with resulting uniformity in bearing pressure over the entire area.

Ratio of Length to Diameter: The modern tendency is toward shorter and more rigid bearings, the lengths being less than the diameter for some types. The rigidity obtained with a short bearing is conducive to maintaining a uniform pressure film over the bearing area. Excessive length, especially if accompanied by too much deflection, results in a waste of power, whereas insufficient length for a given load, velocity, and lubricating condition may cause abrasion and seizure due to excessive unit pressures. Some ratios of length to diameter which have been used follow: Marine engine main bearings and crankpins, 1 to 1.5; stationary engine main journals, 1.5 to 2.5; stationary engine crankpins, 1; ordinary heavy shafting with fixed bearings, 2 to 3; ordinary shafting with self-adjusting bearings, 3 to 4.

Beaver-Tail Stop. The "beaver-tail" stop mechanism is used in conjunction with spur gearing to prevent or minimize inertia shock or impact at some point in a repeated cycle where a clutch is thrown or tools are brought into contact with each other or with the work. The name "beaver-tail" is applied to this mechanism because of the shape of the cam which forms an important part of it. The driving pinion revolves continuously, and drives its mating gear through ordinary gear teeth except when the "beaver-tail" mechanism comes into action, at which time the motion of the gear is controlled by the two rollers and the "beaver-tail" cam. If driven gear is to be stopped once during each revolution, one cam is attached to it. If two stops per revolution are required, two cams are used. The teeth of the driven gear are cut away at each stopping position, and the large developed tooth or cam takes their place.

Rollers on the driving pinion are diametrically opposite each other, and their centers are on the pitch circle of the pinion. When the beginning of the blank space on the gear reaches the pinion and during a partial revolution of the pinion, one roller moves along the "beaver-tail" cam and brings the gear to rest with a harmonic motion. The center of the roller at the point of engagement coincides with the point of tangency of the two pitch circles, so that engagement takes place without shock. The driven gear is locked during the brief dwell which occurs while the rollers are revolving about a concentric part of the cam. After the dwell, the other roller engages the cam and accelerates the gear until it has the same speed as the pinion, when the gear teeth mesh and the ordinary gear drive is resumed. Both stopping and starting are accomplished with harmonic deceleration and acceleration, so that there is no shock to the mechanism (except from possible backlash) due to the reversal of strains.

Bel. The *bel* is the fundamental division of a logarithmic scale for expressing the ratio of two amounts of power. The number of bels denoting such a ratio is the logarithm to the base 10 of this ratio. Thus, if P_1 and P_2 are two amounts of power, and N the number of bels denoting their ratio, then

$$N = \log_{10} \frac{P_1}{P_2} \text{ bels}$$

The *decibel* is one-tenth of a bel and is commonly abbreviated as db. This unit is used extensively in the measurement of sound volume in telephone and radio transmission and reception, and in noise measurements of various kinds.

Bell and Spigot Joint. The usual term for the joint in cast-iron pipe. Each piece is made with an enlarged diameter or bell at one end into which the plain or spigot end of another piece is inserted when laying. The joint is then made tight by cement, oakum, lead, rubber, or other suitable substance, which is driven in or calked into the bell and around the spigot.

When a similar joint is made in wrought pipe by means of a cast bell (or hub), it is at times called "hub and spigot joint" (poor usage). *Matheson joint* is the name applied to a similar joint in wrought pipe which has the bell formed from the pipe. Applied to fittings or valves, the term means that one end of the run is a "bell," and the other end is a "spigot," similar to those used on regular cast-iron pipe.

Bell Center Punch. A prick or center punch which is mounted inside of a cone-shaped bell-mouthed casing. By placing the bell-mouthed casing over the end of a bar, the prick punch is automatically located at the center of a bar with fair accuracy.

Bellcrank. A bent lever having two arms at an angle to each other and pivoted at the point where the two arms join. Frequently, the two arms are at a right angle to each other.

Bell Metal. Bell metal is a bronze containing either 80 per cent of copper and 20 per cent of tin, or 78 per cent of copper and 22 per cent of tin. As the name indicates, it is used for bells. Many attempts have been made to substitute cheaper metals for the copper and especially for the large percentage of tin, but these have proved unsuccessful, because good tone values have not been obtained from alloys not composed of the metals mentioned and in the proportions given.

Belmalloy. A pearlitic malleable iron having physical properties developed by an electric melting and continuous annealing process that are similar in many respects to the properties of

0.40 per cent carbon cast steel. The tensile strength ranges from 70,000 to 80,000 pounds per square inch; yield point, from 45,000 to 50,000 pounds per square inch; and hardness, from 179 to 207 Brinell. Can be machined more easily than steel castings, although not so easily as regular malleable-iron castings. Suitable for applications where high tensile strength, considerable hardness, comparative ease of machining, and freedom from internal stresses are of particular value in castings.

Belt Cements. Two kinds of cement are used for joining the ends or plies of leather belting to produce what is generally termed an endless belt. One kind is referred to as "regular" belting cement and the other kind as "waterproof" belting cement. Both kinds can be obtained from the leather belting manufacturer, and either has ample strength and durability. When a belt is to be used in a dry place, where it is not subjected to moisture, the regular belting cement is employed, while the waterproof cement is used in damp places and where the belt comes in contact with water.

Preparation of Belt Cement: The regular cement usually comes in cakes or lumps, which are dissolved in water in a double-jacketed glue pot. Any pot with a double-jacket—that is, with an inner and an outer vessel, so that the heat reaches the cement through the medium of hot water, and not directly from the flame, will serve the purpose, though it is better to use the Safety or Underwriter's glue pot, for in it the glue may be maintained under heat directly at the job, and without risk of causing fire.

The cement should be made hot, but it should not be permitted to boil. It should be reduced with hot water to a proper consistency to spread easily, and must be applied "piping" hot, to get the best results. It is desirable, too, that it should be applied fresh, and it is better not to attempt to use over the remains of a previous melting, if it is old and hard. The pot and the brushes must be kept clean, as the base of this cement, animal glue, is subject to putrefaction.

Waterproof Belting Cement: The waterproof cement is essentially a liquid celluloid and its application places a layer of celluloid between the two surfaces of the lap, in which the leather fibres become embedded. It is unaffected by water, in any period of time, because both its base and its solvent are materials that are not soluble in water. It should be used on all belts that are exposed to damp conditions, or on which water may leak.

The solvent is very volatile, and highly inflammable, and it must be kept away from any open light. This cement is in a liquid form. Usually it is ready to spread, though after some spreading the remainder will grow thicker and should be reduced by the addition of solvent, which can be obtained from the same

source as the cement. This cement is more like a varnish, and it is used cold.

Application of Waterproof Cement: The surface to be cemented must be thoroughly coated with the cement, well brushed into the fibres of the leather, and then permitted to dry, which, because of the volatility of the solvent, takes place rapidly. When dry, another coat is applied. This coat is spread lightly and is also permitted to dry. When the second coat is perfectly dry, the belt is ready for the third and last coat. Care must be taken to apply the cement evenly and not leave any bare spots.

On belts wider than 12 inches, it is best not to attempt to cover more than a 5-inch cross-section of the belt at one time, since the solvent evaporates very fast, and it is easier to handle a small surface. When applying the last coat, the work must be done quickly. The joint should not be hammered, but rubbed gently or placed between boards, and pressure applied with the bench screws. The joint should "set" for a couple of hours or longer before using the belt.

Belt Conveyors. Belt conveyors are used for carrying and transporting coal, sand, gravel, etc., for comparatively short distances. These conveyors combine a high carrying capacity with low power consumption. The belt on which the material is carried is sometimes flat, the material being fed to it at the center in a narrow stream, but, in most cases, the belt is made to assume the shape of a trough by means of guiding idler pulleys set at an angle with the horizontal and placed at intervals along the length of the belt. Rubber and cotton belts may be used for belt conveyors. The speed at which belt conveyors are run varies from 200 to 800 feet per minute.

Belt Dressings. In many belt dressings a certain amount of resin is used and in almost all dressings some form of graphite. While both of these compositions possess certain adhesive qualities, in time they are sure to injure the fibre of the leather. If leather belting is properly curried, it seldom becomes hard or dry, unless it is working under adverse conditions. Under such conditions it is advisable to use as a belt-dressing tallow mixed with a certain amount of castor oil. The tallow softens the fibres of the leather and the castor oil restores, to a large extent, the adhesive qualities in the belt. Where trouble is experienced through slippage of the belt, a few drops of castor oil on the pulley where the slipping occurs will be found to give good results. The slippage of belts is generally due to the fact that frictional heat causes the grain or pulley side of the belting to become dry. Castor oil tends to soften the grain. A treatment that has proved satisfactory in maintaining a belt's gripping

power consists in saturating the belt with animal grease or fish oil once a month, removing any surplus carefully. Before the grease or oil is applied the belt should be thoroughly cleaned.

Belt Materials. Belts for power transmission may be made either from leather, rubber, canvas, or thin sheet steel. Leather belts are, by far, the most commonly used. Rubber belts are used when the belt is exposed to the weather conditions or to the action of steam, because they do not stretch as easily as leather belts, under these conditions. Canvas belting is used when the materials in contact with the belt and the surrounding atmosphere would affect a leather or rubber belt. Steel belts made from thin flat strips have been introduced within comparatively recent years.

Belts Made of Leather: The best grades of leather belting are made from a comparatively small section of a hide. That part of the hide extending along the spine and for some distance down the sides is firm and close in texture and the strongest for a belt. If the leather is taken too far down the side, it will be flexible and lack strength and closeness of texture. If the strips are cut too long, the ends will be taken from the neck of the animal, which is also inferior stock. A "short lap" belt is one made entirely from that part of the hide which comes from the back of the animal and the strips are not long enough to include any portion of the neck stock. The use of the poorer grades with the best grades of leather belting is particularly bad. The inferior grades soon stretch, throwing almost the entire stress of belt pull on the superior grade. This uneven tension quickly deteriorates the belt. Probably a belt made up in this manner is inferior to that made of the poorer grades throughout. Making the belt of inferior grades throughout has the merit of equalizing the stretch, keeping both parts in even tension. Oak-tanned leather is often considered the best for belting, although many high-grade belts are no longer tanned by the use of oak bark. Assuming that a good grade of leather is used, uniformity in the material is of first importance; that is, the different sections of which the belt is made should all be of the same grade. The belts should also be thoroughly stretched so that they do not have to be "taken up" every few days.

Piping Test for Belt Leather: Leather in the lower half of the hide, with its longer and looser fibres, is softer and spongier than the upper part, and the grain surface of the leather is not so firmly attached to the inner fibre; hence, in bending this leather, it will develop usually into wrinkles or "pipes" in the grain. It is possible to produce "pipes" in almost any piece of leather by bending it often enough and close enough, and

applying sufficient force. A single leather belt should not show piping when bent over a form 2 inches in diameter; or a double belt when bent over a form 4 inches in diameter.

Practically all belly leather stock will show piping under this test, even when it has been rolled hard to prevent it from showing, and hence it is not desirable for belting purposes. Occasionally, pieces from the upper part of the hide will show piping under this test, but regardless of the part of the hide from which the piece is taken, the presence of piping indicates a loose grain and a flabby fibre in the leather, which is not conducive to durability in the belt, and in most cases indicates the presence of belly stock. There is another test to be applied by bending the leather over the same form, with the grain side on the outside, to detect cracking in the grain, and if this test develops a series of minute cracks running across the width of the belt, it may be deduced that the material either is not properly tanned or is not properly curried, and that it is not suitable for good belts.

Belts Made of Fabrics: Among fabric belts (aside from rubber belts), the solid woven, impregnated cotton belt seems to take first place as a substitute for leather belts. Balata and stitched canvas belts, which are made up of plies similar to rubber belts, apparently have not been able to get a firm hold in the field of power transmission. A comparison of these types of belting shows that balata and stitched canvas belts possess a definite maximum of power transmission beyond which it is impossible to go, and that this maximum capacity is far below the capacity of leather belts. The solid-woven cotton belt seems to be the only fabric belt which nearly approaches the capacity of a leather belt. The stretch of this cotton belting in service is about the same as leather, and, like all cotton belting, it is affected by moisture and high temperature, although the effect is the reverse of the effect on leather. In damp places leather stretches and cotton shrinks; the changes in length, however, due to changes in atmospheric conditions, are much less for cotton than for leather, due to the treatment which cotton belts undergo. Although solid-woven cotton belts do not have the durability of leather belts, their flexibility is great and they can be used on the smallest pulley without much loss through bending, and without subjecting the belt to greater strain. They are unaffected by grease, grit, mineral oils, or heat.

Belt Power-Transmitting Capacity. Power ratings for belt drives vary considerably, according to different authorities and investigators, even for belts of the same kind and applied under similar conditions, as will be seen by a comparison of the con-

clusions found in text-books, articles, and the literature published by belt manufacturers. The general formula for determining the power rating follows:

$$H = \frac{SVW}{33{,}000}$$

In this formula, $H =$ horsepower; $S =$ effective belt pull, in pounds per inch of width; $V =$ belt velocity, in feet per minute; and $W =$ belt width, in inches.

The effective pull or difference between the tensions on the tight and slack sides is the variable factor. This factor is affected by belt velocity and arc of pulley contact, by belt thickness and its relation to the pulley diameter, as well as the kind and quality of the belting. Even for the same belt quality, wide differences of opinion exist as to the amount of pull per unit of width or area that is conducive to the best results when initial cost, durability, and everything pertaining to it are allowed for. If the working load is excessive, the life of belting will be reduced accordingly and the load on the bearings increased. On the other hand, if belts are given too low a rating, this means that wider and more expensive belts will be installed than is necessary. Somewhere between these extremes is the most economical rating, which is based, not only upon the initial cost of the belt but also upon all subsequent costs connected with that particular installation.

Belts, V-type. Belts of the V-type provide a compact, resilient transmission and they have been applied extensively to automotive drives for fans, generators, and water pumps, and to many miscellaneous types of machines and industrial transmissions. Only the angular sides of a V-belt should be in contact with the sides of the pulley groove. The belt is approximately flush with the top of the pulley and the pulley groove should be deep enough to provide a clearance space at the bottom of about 1/8 to 3/16 inch to insure a belt contact at the sides only. A multiple V-belt drive is commonly used instead of a single belt when required to increase the power-transmitting capacity. The driving and driven pulleys of these multiple drives are grooved for each belt, the grooves being spaced to provide clearance between the belts.

Sizes of V-belts: The five common sizes of V-belts used for miscellaneous industrial applications include both smaller and larger sizes than those in the S.A.E. standard; moreover, the widths and thicknesses of industrial V-belts differ more or less from those conforming to the S.A.E. standard. The sizes of industrial V-belts are commonly designated by the letters A, B, C, D and E, or by the use of these letters in conjunction with the

belt width at the top and its thickness. The sizes follow: A, ½ by 11/32 inch; B, 21/32 by 7/16 inch; C, ⅞ by ⅝ inch; D, 1¼ by ¾ inch; E, 1½ by 1 inch. The first dimension indicates the width at the top and the last one the belt thickness.

Pulley or Sheave Groove Angles: According to the S.A.E. Standard, the included angle of the pulley groove varies from 28 to 38 degrees for different pulley diameters. The included angle of the belt itself, according to the S.A.E. specifications, is to be determined by the belt manufacturers to meet the specific requirements of each application.

Speed Ratios: Transmissions of the V-belt type commonly are applied to ratios varying from 1 to 1 up to 7½ to 1, and higher for some applications. As a general rule, the ratio should not be high enough to reduce the arc of belt contact with the smaller pulley below about 120 degrees.

Minimum Sheave Diameters: If the sheaves are too small in diameter, excessive bending of the belt will shorten its life and may result in considerable internal friction. The minimum pitch diameter of the sheave for one installation or kind of service might not be the minimum for different conditions; however, as a general rule, the minimum pitch diameters would be as follows: 3 inches for belt size A; 5.4 inches for belt size B; 9 inches for belt size C; 13 inches for belt size D; 21.6 inches for belt size E.

Center Distance between Sheaves: Belt transmissions of the vee type are particularly adapted for short-center drives, and short-center distances are recommended especially for high speeds. One rule is to make the center distance slightly larger than the diameter of the larger pulley and smaller than the sum of the diameters of both pulleys; however, both longer and shorter distances are entirely practicable. There should always be provision for a center distance adjustment not merely to compensate for any slight stretching which might occur but to facilitate installing new belts without forcing them over the sheaves. Belts of the V-type do not require initial tension. In fact, it is only necessary to adjust the center distance so as to avoid excessive slack or undue sagging of the belt.

V-Belt Speeds: The maximum speed depends upon the class of service and may be decidedly affected by the diameters of the sheaves. High speeds tend to shorten the life of the belt; on the other hand, if the speed is unnecessarily low, either a larger belt or more belts will be required for transmitting a given amount of power. In many installations, speeds should be limited to about 2500 to 3000 feet per minute, especially if the pitch diameters of the sheaves are near the minimum diameters previously given. On larger sheaves, under favorable conditions, the speeds may range from 4000 to 7000 feet per minute.

Belt Tension Scale. See Tension Scales for Belts.

Benches. The height of work-benches usually varies from 32 to 36 inches from the floor to the top of the bench, the height depending somewhat upon the nature of the work, lighter work being done on higher benches. For general purposes, the height should be about 34 inches; the width should be about 30 inches, and the top is ordinarily composed of heavy planks, 2 or 3 inches thick, in the front, and lighter 1-inch boards in the back. The thickness of the front planks is varied in accordance with the weight of the work for which the bench is intended. Maple and ash are considered the best woods for bench planking. The preferable positions for benches, especially if used for fine accurate work, is the north side of the building, because the light on that side is more even throughout the day.

Bench Lathe. The modern bench lathe finds wide application in the manufacture of small parts requiring considerable accuracy, as well as in fine tool work, where its facility of operation and its accuracy make it an ideal tool. Bench lathes have been developed to the same high standard of efficiency as the heavier types of lathes, and the design of various attachments has broadened the field of these machines so that they are able to handle a wide range of work. In addition to their adaptation to precision turning and boring operations, bench lathes may be equipped with attachments for milling and grinding, for chasing, cutting, and milling screw threads, for turret work, filing, and a variety of other operations. Many of these attachments, such as those for milling, grinding, threading, etc., are standard equipment supplied by bench lathe manufacturers, but many special attachments are also used in connection with bench lathe practice.

Bench Lathe Milling Attachments. Bench lathes are often used for milling in connection with such operations as fluting special reamers, taps, counterbores, or other cutters, and making small punches, dies, pinions, etc. Milling attachments vary in regard to the range of adjustment and methods of applying to the machine. For instance, some have a single vertical slide with or without a swivel or angular adjustment and are mounted upon the regular compound slide in order to obtain cross and lengthwise movements. Other milling attachments are mounted directly on the bed in front of the headstock, and have their own slides, as well as swivels for angular adjustment in two planes. Another variation consists in bolting the attachment to one end of the bed, instead of locating it on the bed or slide-rest. One design is held to the right-hand end of the bed, and another to the left-hand end, the headstock in the latter case being reversed. The most common practice is to use the milling attachment for holding the

work and the lathe spindle for driving the cutter, but some attachments are designed to drive the cutter, which operates upon work while it is held in the lathe spindle.

Bench Lathe Tailstocks. In bench lathe practice, the tailstock is frequently used as a means of holding and feeding various classes of tools. Tailstocks for bench lathes are made in several different forms. The type intended primarily for supporting one end of centered work is designed along the general lines of the well-known engine lathe tailstock. Then there is a lever-operated tailstock for drilling, reaming, counterboring, and similar operations. Another form is operated through a rack and pinion in conjunction with a hand-lever. The cross-slide adjustment provided in this case is useful for recessing, facing, and counterboring. The "half-open" tailstock is employed for light operations such as drilling, reaming, lapping, and the cutting of very small threads with taps or dies, while the revolving-spindle tailstock is applied to certain drilling operations. The "sliding" or "open" tailstock is similar to the half-open design, except that it has full or complete bearings. The spindle has a knob at one end and is moved by hand the same as the spindle of a traverse grinder.

Bench Lathe Tool-Slides. For certain operations on bench lathes, it is preferable to operate the tool-slide by a hand-lever instead of using an ordinary feed-screw, on account of the more rapid movement obtained. The connection between a hand-lever and slide may be direct or through a pinion meshing with a rack attached to the slide. If the manipulation of the ordinary feed-screw is too slow and a direct-acting lever does not give quite the feeding power needed, then a hand-lever which acts through the medium of a rack and pinion is the best combination.

Bench Lathe Traverse - Spindle Grinder. The traverse-spindle grinding attachment is so named because the spindle is free to slide in its bearings, and is traversed either by means of a knob at the rear end, or by placing the belt pulley between the thumb and forefinger. Such attachments are generally used for grinding or lapping holes, but they are also very satisfactory for external grinding, particularly on short end surfaces and whenever a light sensitive control is essential. Many light drilling, reaming, and milling operations are also done with the traverse-spindle attachment which is also called a "push spindle" and a "slide-spindle" attachment.

Bendalloy. Alloy composed of bismuth, lead, tin, and cadmium, having a melting point of only 160 degrees F.—considerably less than the temperature of boiling water. Used as a filler material in tube-bending operations to prevent flattening at the bent sec-

tions. The name Cerrobend has more recently been used in referring to this material.

Bending Brake. See Brakes for Bending.

Bending Dies. Dies of this class are designed for bending sheet metal or wire parts into various shapes which are usually irregular and are produced either by pushing the stock into cavities or depressions of corresponding shape in the die or by the action of auxiliary attachments such as slides, etc., which are operated as the punch descends. A simple form of bending die would be one having an upper part or punch shaped to correspond with a depression in the die-face; such a bending die is sometimes employed for bending flat, sheet-metal plates into an irregular shape. When the material to be bent is elastic or springy, the die must be made to allow for this, or so that the part is bent slightly beyond the required shape or angle to compensate for the backward spring when the pressure is released. Determining this allowance is a matter of experiment.

Bending Pipes and Tubes. See Pipe Bending.

Benedict Metal. A nickel silver that has the following nominal composition: copper, 57 per cent; tin, 2 per cent; lead, 9 per cent; zinc, 20 per cent; nickel, 12 per cent. Impurities that may be present in the sand cast form are: iron, 1.50 per cent, max.; manganese, 0.50 per cent, max. It is used for hardware fittings, valves, valve trimmings, plumbing fixtures, ornamental castings, statues and for free machining work. In the sand cast condition it exhibits the following physical properties: tensile strength, 34,000 pounds per square inch; yield strength (0.5 per cent elongation under load), 15,000 pounds per square inch; per cent elongation, 20; per cent reduction of area, 20; Brinell hardness number (500 kilogram load), 60; density, 8.95 grams per cubic centimeter at 68 degrees F.

Beneficiation of Iron Ore. The term "beneficiation" is applied to those processes used for the improvement of ores which result in producing an ore which contains a greater percentage of the metal to be extracted than the original mined product. It is also applied to those methods which change the physical and sometimes the chemical properties of the ore so that it will meet the requirements for a commercial product. In the past, the term "beneficiation" has been applied to ores of precious metals only, but at the present time it is also applied to the ores of other metals, such as iron. When the process produces a richer ore, more than one ton of raw material is required to produce one ton of the beneficiated ore; for example, an ore containing 40 per cent of iron may be concentrated so that it yields an ore contain-

ing 60 per cent of iron, but it is evident that at least $1\frac{1}{2}$ tons of the 40-per-cent ore must be used to produce one ton of the concentrated 60-per-cent ore. There are various methods by means of which beneficiation of iron ore may be carried out.

Beryllium. A rare metallic element also known as *glucinum*, belonging to the same group of metals as magnesium, the chemical symbol of which is Be. (When the name "glucinum" is used, the chemical symbol Gl is employed.) The metal is malleable. Its specific gravity is 1.64, its atomic weight, 9.1, and its melting point about 1800 degrees C. (about 3275 degrees F.).

Beryllium Copper. By alloying with copper, small amounts of beryllium and nickel, an alloy is obtained having high tensile strength, high fatigue limit and hardness, and also with relatively high electrical and thermal conductivity, depending upon the heat-treatment. This alloy has many applications in the electrical and aircraft industries or wherever strength, corrosion resistance, conductivity, non-magnetic and non-sparking properties are essential. Beryllium copper is obtainable in the form of sheets or plates, strips, rods, wire, and tubes.

Composition: The patented composition follows: Beryllium, 2 to 2.25 per cent; nickel, 0.25 to 0.50 per cent; iron, usually less than 0.1 per cent; copper, remainder.

Mechanical Properties: Soft annealed beryllium copper sheet has a tensile strength of about 70,000 pounds per square inch, and this may be increased to about 175,000 by average heat-treatment. By cold-working and heat-treating, the strength may be increased to about 195,000 pounds per square inch.

The hardness of beryllium copper sheets 0.050 inch thick is about 110 Brinell for soft annealed sheets and 340 Brinell when average heat-treatment is applied. The specific gravity is 8.23. The foregoing data apply to an alloy containing 2 to 2.25 per cent beryllium.

Bessemerizing of Matte. A method of refining copper which is similar to the Bessemer process for making steel from pig iron; see *Manhes process*.

Bessemer Ore. An iron ore containing such a small percentage of phosphorus that it is suitable for making pig iron which can be converted into steel by the acid Bessemer process. Such ore must not contain more than 0.07 per cent of phosphorus.

Bessemer Pig Iron. A name applied to iron which contains so little phosphorus and sulphur that it can be used for conversion into steel by the original or acid Bessemer process (restricted to pig iron containing not more than 0.10 per cent of phosphorus).

Bessemer Process. The Bessemer process of converting iron into steel is also known both as the *pneumatic* and the *fuelless;* by this process, the carbon, silicon, and manganese of molten iron, and often the phosphorus and sulphur as well, are oxidized and removed by air forced through the metal. Hence, in the Bessemer process, the product of the blast furnace may be converted into steel, thus reducing the cost of raw material for all but the highest grade of steel. The process was invented and patented in England by Sir Henry Bessemer, in 1855.

In the Bessemer process, the impurities are removed by passing air through the molten metal in many fine streams and so rapidly that the heat produced by the oxidation of these impurities is sufficient to raise the temperature of the iron from just above the melting point of cast iron to considerably above the melting point of steel.

After the converter is charged, for which purpose it is placed in a nearly horizontal position, the blast is turned on, and then the converter is placed vertically. The blast pressure is sufficient to prevent the molten iron from passing through the tuyeres into the wind box. At first, only the nitrogen of the blast passes through the metal, as the oxygen is consumed in the oxidation of silicon and manganese; as a result, no flame appears at the mouth of the converter; but, when the silicon and manganese are nearly gone, the carbon is converted into carbon monoxide by the blast, which burns at the mouth of the vessel, producing an intensely bright flame that rapidly increases in size. When all the carbon is burned, the flame drops quite suddenly, which is a sign that the process is completed. The steel is then discharged by again placing the converter in a horizontal position and shutting off the blast.

Acid Process: The original, or acid, Bessemer process is limited to comparatively fine pig irons, because dephosphorization and desulphurization do not take place. In this process, the bottom is made by putting the hard-burned fireclay tuyeres in position and then dumping in ganister until the layer is from 26 to 30 inches thick; the usual life of this bottom is from 30 to 35 heats, although some burn out in a single heat, while others last for 50 or 60 heats.

Basic Process: The basic process makes available, for the making of steel, iron that is too high in phosphorus for the acid Bessemer process and for economical use in the ordinary basic open-hearth process. It was at first known as the *Thomas-Gilchrist process,* from its inventors S. G. Thomas and P. C. Gilchrist. It differs from the acid process in that the slag is made very basic by the addition of considerable lime, the converter lining is basic, the process is not arrested at the drop of

the flame, and the oxidation of phosphorus is the source of the heat. In the basic process, the converter used is from 50 to 60 per cent larger than the acid converter for the same iron charge. Its lining is from 12 to 24 inches thick at the bottom and from 8 to 16 inches thick at the nose; its bottom is from 20 to 26 inches thick. The average life of this converter is about 100 heats.

Because of their short life, basic converters are generally installed in sets of three, so that two converters may be working while the third is being relined. In the acid method, the blast has a pressure of from 20 to 30 pounds to the square inch and the heat is completed in from 7 to 12 minutes; in the basic process, the blast has a pressure of from 25 to 35 pounds, and the heat requires from 15 to 18 minutes. The action during the first part of the basic process is similar to that of the acid; but the latter part, known as the "afterblow," is distinctive; it is at this stage that the phosphorus is removed.

Bessemer Steel. Steel made in a Bessemer converter in which the carbon and impurities are removed from the charge of molten pig iron by blowing air up through the metal. A steel of fair quality is made by this process, which is cheap and rapid. Most steel is now made by the open-hearth process.

Bevel Gear. Bevel gearing is used for transmitting motion between two shafts located at an angle to each other (usually a right angle) and normally having center lines which intersect or lie in the same plane. By using special teeth, it is possible, as in "hypoid gears" and also "skew" bevel gearing, to have the center lines of the driving and driven gears in different planes, one shaft being offset somewhat relative to the other shaft.

When the number of teeth in two gears is the same they are called *miter gears,* the pitch cone angle of each gear being equal to 45 degrees. The term *acute angle bevel gearing* is applied when the center angle or angle between the axes of the shafts is less than 90 degrees. *Obtuse angle bevel gearing* connects shafts having a center angle greater than 90 degrees.

If the pitch cone angle of a bevel gear equals 90 degrees, the gear is known as a *crown gear,* the pitch cone in this case being a pitch plane or disk. If the pitch cone angle exceeds 90 degrees, the gear is an *internal bevel gear.* The teeth of two bevel gears in mesh converge toward a common center. This converging tooth form must be obtained in cutting the teeth by a generating process, although an approximate shape can be obtained by the formed cutter process. See also Hypoid Gears; Skew Bevel Gears; Spiral Bevel Gears.

Bevel Gear Formed Cutter. A bevel gear cutter is made thinner than a spur gear cutter because it must pass through the narrow tooth spaces at the inner ends of the teeth. For 14½-degree involute teeth, there are eight cutters numbered from one to eight for each pitch and suitable for cutting bevel gears from a 12-tooth pinion to a crown gear. The cutter to use, in any case, must not only be of the required diametral pitch but the right number in the series. The number of the cutter depends upon the number of teeth in the gear or pinion. When cutting miter gears, only one cutter is needed, but, if one gear is larger than the other, two cutters of the same pitch but of different numbers may be required.

The number of teeth for which to select the cutter is not the actual number of teeth in the gear, but is found as follows: Divide the actual number of teeth in the gear by the cosine of the pitch-cone angle. For instance, if the bevel gear is to have 35 teeth or 12 diametral pitch and the pitch cone angle is 60 degrees, the number of teeth for which to select the cutter equals $35 \div 0.5 = 70$. Therefore, a number 2 cutter of 12 diametral pitch would be used, since this number in the series is intended for numbers of teeth from 55 to 134. Cutter number 1 is for cutting gears with number of teeth ranging from 135 to a rack; number 2 from 55 to 134; number 3 from 35 to 54; number 4 from 26 to 34; number 5 from 21 to 25; number 6 from 17 to 20; number 7 from 14 to 16; and number 8 from 12 to 13.

Bevel Gear Generating Processes. In cutting spur gears by generating methods, the rack of involute gearing is represented either directly by the cutter used, or indirectly as when a circular form of cutter is generated from the rack. The relation between a rack and spur gear is similar to that of a crown gear to a bevel gear; thus the pitch surface of a rack and also of a crown gear coincides with a plane. The teeth of a crown gear are also straight sided like those of a rack, although of converging form, and the inclination of each side corresponds to the pressure angle. The cutting tools of bevel gear generators, therefore, represent the crown gear and when a bevel gear is being cut the tooth curves are derived by imparting to the work and to the cutting tool the same relative motion that would be obtained if the gear being cut were rotating in mesh with the crown gear. In addition to this generating motion, provision must be made in a practical design of machine for giving the tool or tools a reciprocating motion for cutting, and an indexing movement to the work in order to cut equally spaced teeth around the entire gear.

The generating motion on some other machines is obtained by rolling the gear being cut, relative to the cutting tool (representing a crown gear tooth) just as though this gear were finished and rolling around a stationary crown gear. Thus all the generating motion is applied to the work; the cutting tool is simply given a reciprocating motion for planing. A common type of bevel gear generator is so designed that the generating action is applied to both the work and to the cutting tools. In this case the action is similar to that of a crown gear rotating in mesh with the gear being cut, each gear revolving about a fixed axis.

Bevel Gears, Gleason Systems. There are three bevel gear systems originated by the Gleason Works and widely used, namely the *Straight Bevel Gear System*, the *Spiral Bevel Gear System* and the *Zerol Bevel Gear System.*

Straight Bevel Gear System: This system provides for a working depth equal to 2.000 inches ÷ diametral pitch and a clearance equal to (0.188 inches ÷ diametral pitch) + 0.002 inch. The use of stub teeth is not recommended because the reduction in contact increases noise and decreases wear resistance. The basic pressure angle is 20 degrees but a 14½ degree pressure angle may also be used. The addendum on the pinion is long and that on the gear is short except when the numbers of teeth in gear and pinion are equal, the amount of departure from equal addendums varying with the ratio. The recommended ratio of face width to cone distance ranges from 0.25 to 0.3.

Spiral Bevel Gear System: This system provides for a working depth equal to 1.700 inches ÷ diametral pitch and a clearance equal to 0.188 inches ÷ diametral pitch. The basic pressure angle is 20 degrees but pressure angles of 14½ and 16 degrees may also be used. As in the case of straight bevel gears, long and short addendums are used and face widths are the same as those for the Straight Bevel Gear System.

Zerol Bevel Gear System: The teeth of Zerol bevel gears are curved but lie in the same general direction as the teeth of straight bevel gears. They may be thought of as spiral bevel gears of zero spiral angle and are manufactured on the same machines as spiral bevel gears. The face cone elements of Zerol bevel gears do not pass through the pitch cone apex but instead are approximately parallel to the root cone elements of the mating gear to provide uniform tooth clearance. The root cone elements also do not pass through the pitch cone apex because of the manner in which these gears are cut. Zerol bevel gears are used in place of straight bevel gears when generating equipment of the spiral-type but not of the straight-type is available, and may be used when

hardened bevel gears of high accuracy (produced by grinding) are required.

Bilateral Tolerance. A bilateral tolerance is a tolerance given in two directions (plus and minus) from the basic dimension. For examples of both bilateral and unilateral tolerances see under Tolerances.

Billet. A "billet," as the term is applied in rolling mill practice, is square or round in section and from 1½ inches in diameter or square to almost 6 inches in diameter or square. Rolling mills used to prepare the ingot for the forming mills are termed "blooming mills," "billet mills," etc.

Billet Mills. See under Rolling Mills.

Binary Alloy. An alloy containing two elements. When the term is used in regard to iron or steel, it refers to a material that has one alloying element in addition to iron. Since carbon is always present in steel, plain carbon steel is the typical binary iron alloy.

Binder. The material used for holding together the sand in a dry sand core is known as a binder. Various dry compounds made from resin, dextrine, coke dust, and pitch, as well as pastes made from flour, are used as core binders. Linseed, fish, and mineral oils, and molasses and glue dissolved in water, are also used.

Birmingham Wire Gage. The Birmingham or Stubs iron wire gage is used for seamless tubing, sheet spring steel, strip steel and to some extent for galvanized iron telegraph wire. (Stubs iron wire gage differs from Stubs steel wire gage.) The Treasury Department of the United States for many years used this gage in connection with importations of wire, and the adoption of succeeding tariff acts with provisions for the assessment of duty according to gage numbers gave legislative sanction to the gage, but, in 1914, its use by the Treasury Department was finally abandoned.

Bismuth. Bismuth is a metallic element, which occurs as pure metal in veins in gneiss or clay-slate, and is frequently found in combination with ores of silver and cobalt. It is found in Saxony and in Bohemia, and also in Cornwall, England, but it is most abundant in Bolivia, which is the chief commercial source of the metal. Bismuth is a very brittle metal with a white-crystalline fracture and a reddish-white color. One of its important qualities is that it expands on passing from the molten to the solid state, and that it retains this property in a number of alloys; hence, it is frequently used with antimony in type metals, because it fills the mold completely upon solidification. Its most

important use, in fact, is in alloys with other metals, and it forms an important ingredient in many of these.

One of the so-called Britannia metals is composed of 50 per cent of antimony, 25 per cent of bismuth. and 25 per cent of tin. A good alloy for pattern letters contains 15 per cent of antimony, 15 per cent of bismuth, and 70 per cent of lead. An important use of bismuth is in alloys requiring a low fusing point. Fifty parts of bismuth alloyed with 25 parts of lead, 12.5 parts of tin and 12.5 parts of cadmium will melt at a temperature of 149 degrees F. Bismuth added to lead hardens and toughens the latter metal. An alloy consisting of 40 per cent of bismuth and 60 per cent of lead has ten times the hardness and twenty times the tensile strength of lead. Alloys of bismuth with either lead or tin can be easily cast, and fill the molds well. Bismuth alloys have been used to some extent for fusible plugs for boilers, but it has been found that the continued action of heat changes their melting point so that they cannot be depended upon to melt at the right temperature. The U. S. Navy Department specifies pure Banca tin for fusible plugs.

The atomic weight of bismuth is 208.5 (some authorities give the value as 208.0); the chemical symbol is Bi; the specific gravity, 9.8; the weight per cubic inch, 0.354 pound; and the weight per cubic foot, 611.5 pounds. The melting point is 271 degrees C. (520 degrees F.). Its thermal conductivity is lower than that of all other metals, it being 1.8 as compared with 100 for silver; its electric conductivity is from 1.2 to 1.4 (silver = 100); its coefficient of expansion per unit length, per degree F., equals 0.00000975; its specific heat is about 0.0306; and its tensile strength about 6400 pounds per square inch. At atmospheric pressure it vaporizes at temperatures above 1100 degrees C. (2000 degrees F.), but its actual boiling point is about 1400 degrees C. (2550 degrees F.).

Bismuth Bronze. Bismuth bronze is an alloy having the following nominal composition: copper, 45 to 53 per cent; nickel, 33 to 10 per cent; zinc, 20 to 22 per cent; tin, 16 to 15 per cent; bismuth, 1 per cent; aluminum, 0 to 0.1 per cent. It is used for ornaments and hardware.

Bituminous Coal. Bituminous coal, generally known as soft coal, contains from 50 to 75 per cent of carbon and a large percentage of volatile matter, varying from 25 to 50 per cent. The heating value per pound of combustible is from 13,500 to 15,500 B.T.U. Coal of this kind gives out large volumes of smoke, and requires special care in firing. The furnaces for burning this coal must be constructed so as to prevent smoke as far as possible. *Semi-bituminous* coal contains from 75 to 85 per

cent of carbon and has a heating value of from 15,500 to 16,000 B.T.U., per pound of combustible. This coal is softer than the anthracites and has a tendency to produce more smoke, but on account of its high heating value it is one of the best coals for power plant purposes.

Bivalent. A bivalent is a term used to indicate that an atom of one element combines with two atoms of another element. It is also known as *divalent.*

Black Diamond. An inferior variety of diamond used in the industries for truing hard grinding wheels. It is more expensive than *bort,* but is more economical to use for hard wheels.

Black Lead. See Plumbago.

Black-Print. A copy of a drawing similar to a *blueprint,* except that it has black lines on a white background and, therefore, closely resembles an original drawing made with black ink on white paper. Black-prints are used when it is desired to obtain the appearance of an original drawing and when a pleasing presentation of the object represented is the primary consideration. Black-print paper, for making prints having black lines on a white background, is also known as *nigrosine* paper.

Black Putty. An acid-proof cement made by carefully mixing equal portions of well dried china-clay, gas tar, and linseed oil.

Blacksmiths' Taps. A class of taps known as "blacksmiths' taps" has a long taper thread and a very short shank, the shank being only long enough for a square and a collar to prevent the tap wrench from slipping from the square down upon the body of the tap. The taper of the thread is ¾ inch per foot; the size by which the tap is known is measured ⅝ inch from the large end of the thread. These taps are generally made with the standard number of V-threads per inch corresponding to their nominal diameter.

Black Wash. A blackening solution containing carbon applied to large dry-sand and loam cores after baking, to prevent the core sand from burning onto the casting and to assist in parting the core from the surface of the cast iron. The black wash or blackening generally consists of a powder containing graphite or crushed coal or coke in some form. The powder is mixed with clay water, or ordinary water, thus forming a liquid paint which can be applied to the cores with a brush.

Blanchard Lathe. The Blanchard type of lathe is named after the inventor, Thomas Blanchard, who built the first lathe

of this kind in 1822. This machine is designed especially for turning wooden parts of irregular shape, and has been extensively used for turning the stocks of guns and rifles. There is a former or model which corresponds to the shape required. The former is mounted on one side of an oscillating frame which carries on the opposite side the wooden blank to be turned. The former and the blank are rotated at the same speed by gearing, and the turning is done by a rapidly revolving cutter. The cutter is mounted on a carriage and traverses along the bed; at the same time, a wheel which bears against the former or model to be reproduced also moves along with the carriage, and the contact of the model with this wheel causes the frame that supports the work to oscillate in such a way that an accurate copy of the model is turned by the revolving cutter.

Blanched Copper. Blanched copper is an alloy of copper and arsenic, containing 91 per cent of copper and 9 per cent of arsenic. It is used for clock-dials and for the scales attached to thermometers and barometers. The alloy is made by heating copper strips or chips with white arsenic in an earthenware crucible. The copper and arsenic are laid in alternate layers in the crucible, and the top is covered with common salt.

Blank. The term "blank" is commonly applied in the mechanical industries to castings, forgings, sheet-metal parts, etc., which are in a preliminary unfinished form. For example, the casting or forging of a gear, is a gear *blank* before the teeth are cut. In press work, a die cuts a flat *blank* from a sheet of stock, preparatory, in many cases, to drawing, forming or bending operations for obtaining the finished form.

Blank Diameter for Sheet-Metal Drawing. Before making a blanking or drawing die, it is necessary to determine how large the flat blank must be in order to produce a shell or cup of the required form. If the stock did not stretch while being drawn or was not ironed out and made thinner, the diameter of the blank could be determined accurately by calculating the area of the finished article and then making the blank the corresponding area. The kind of metal to be drawn, that is, whether steel, brass, copper, aluminum, etc., and whether it is hard or soft, also affects the size of the blank to some extent.

Owing to the uncertainty of obtaining the right blank diameter by calculation, a common method of procedure, especially when constructing drawing dies for parts requiring more than one or two drawing operations, is to make the drawing part of the die first. The actual blank diameter can then be determined by repeated trials, after which the blanking part of the die may be finished. The blank diameter for a plain cylindrical shell having

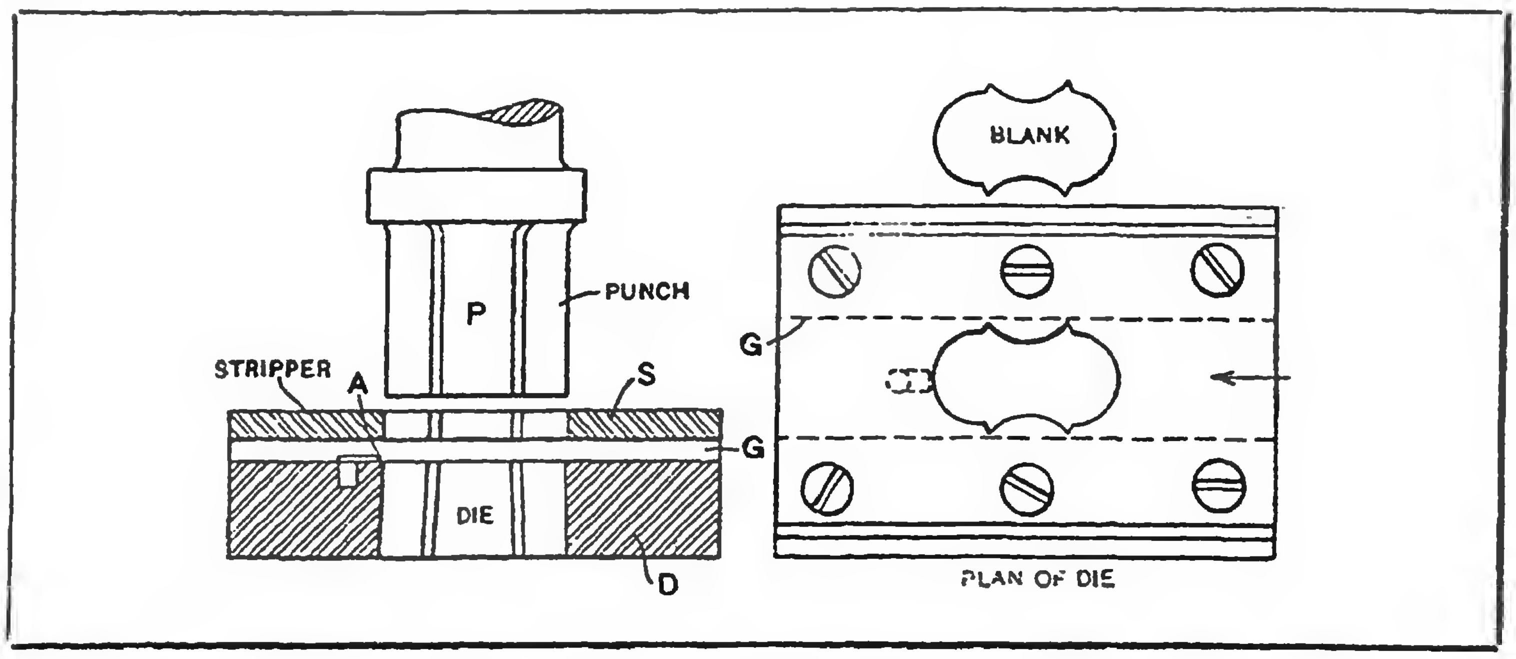
sharp corners can be determined approximately by the following rule: Multiply the diameter of the finished shell by the height; then multiply the product by 4 and add the result to the square of the finished shell diameter. The square root of the sum thus obtained equals the blank diameter.

Blank-Holder. When a flat blank is drawn either in a combination or double-action die, the outer part is subjected to pressure by a blank-holder; consequently, no wrinkles can form if the die is properly constructed. After the metal has passed from under the blank-holder and over the edge of the die, it is no longer confined and, as it is being drawn into a smaller circumference, the natural tendency is to wrinkle. Such wrinkles are sometimes known as *body wrinkles* to distinguish them from the *flange wrinkles* which result when there is insufficient pressure between the blank-holder and the die.

Blanking Dies. Dies of the "blanking class" are used for cutting blanks usually from flat sheets or strips of stock; such blanks may or may not be drawn, formed or bent, either by other parts combined with the blanking members, or by means of separate dies. If the chief or only function of the die is to cut blanks, it is a blanking die; if the blanking operation is followed by a more important operation in the same die such as drawing, then the term drawing die would be applied, the blanking part being considered a secondary feature of the design.

Plain blanking dies are the simplest of all types of dies. A blanking die consists essentially of: a die-block such as *D* in the illustration which has an opening that conforms to the shape of the part to be cut or blanked out; a *punch P*, which accurately fits the opening in the die-block and, by a shearing action, does the cutting as it descends into the die-block opening; and a *stripper plate S*, which strips the stock off of the punch-block, as the latter ascends. The opening in the stripper plate conforms to the shape of the punch and is either slightly larger to provide a little clearance, or close fitting to steady the punch. Between the stripper plate and die-block there is a *guide G*, which serves to keep the stock in alignment with the die opening as it is fed along. A most important point in making blanking dies for odd shapes is to lay them out so that the minimum amount of metal will be converted into scrap.

Blast Furnace. Blast furnaces are used for extracting the iron from iron ores; the deoxidation of the iron ore and the removal of the impurities are carried on simultaneously. Carbon, generally in the form of coke, is the deoxidizing agent, although anthracite and charcoal are also used, while limestone is added as a flux to render the slag, as the impurities are called when



Plain Blanking Punch and Die

mixed with the lime and ashes of the fuel, more fusible. The combustion of the deoxidizing agent furnishes the heat necessary to melt the resulting iron and slag. When drawn from the furnace, the iron is run into molds and cast into bars called *pigs.*

The body of a blast furnace is the preliminary heating area for the fuel and ore. It occupies by far the largest proportion of the furnace capacity, from the *bosh* at the bottom, to the *throat* at the top. Generally the sides of the body are slightly tapered, the diameter being larger at the lower end where it joins the bosh and smaller at the top where it joins the throat. The angle of inclination is usually between 3 and 8 degrees. This taper makes it easier for the charge of ore and fuel to descend in the furnace.

Blast Furnace Fuels. Charcoal was the principal blast furnace fuel for centuries, and in America it was but natural that it should be used, for timber was plentiful and much of it had to be cut to clear the soil. Both raw coal and coke, however, had been used in Europe for smelting iron ores prior to 1651, but in this country it was not until 1855 that anthracite iron passed charcoal iron in volume of output; in 1869 bituminous fuel also passed charcoal. In 1875, bituminous fuel passed anthracite, and has now become the principal fuel. Beehive coke was used at first but this reached its maximum production in 1916, only to be passed by by-product coke in 1919.

Blast Furnace Gas. The waste gas produced by a blast furnace, containing from 20 to 26 per cent, by weight, of carbonic oxide. It is used for heating the blast, for generating steam, and for operating gas engines. Before the gas can be used in gas engines, however, it must be cooled, the dust washed out, and the gas filtered. The first large blast furnace gas engine was built in 1900. Large steel works develop thousands of horsepower from blast furnace gas.

Blast Furnace Slag. The waste material formed when converting iron ore into pig iron in the blast furnace. The slag is composed of silica, lime, and alumina, some of these ingredients originating from the ore and fuel, but most of them are from the flux used.

Bleed. A term used in foundry and blast-furnace practice to designate the condition when the metal has solidified on the surface but is not set solid on the inside, so that, if the surface is broken, the molten metal will run out, or "bleed," through the rupture.

Blind Hole. In machine construction, a hole which does not pass through a part but has a closed inner end is commonly known as a "blind hole."

Blister Copper. If metallic copper is produced in a furnace by smelting copper sulphide and copper oxide, the resulting product is known as *blister copper*. The name is derived from the fact that the escape of the sulphur dioxide in bubbles gives rise to small cavities or blisters in the mass of the copper.

Blister Steel. Blister steel is produced by the carburization of wrought iron by heating it in a furnace in contact with carbonaceous matter. It is an obsolete method, known as the *cementation process*, and was, in the early days, employed for producing tool steel. After carburizing the carburized bars, called *blister steel*, were then cut up into small pieces and remelted in a crucible, and from that poured into moulds.

Block and Tackle. "Block and tackle" is the name given to a hoisting device in which the pull on ropes passing over pulleys or sheaves lifts the load. The pulley, in its simplest form, is a grooved wheel turning within a frame or shell to which a hook, eye, or strap is fastened. The combination of shell, pulley, and hook is known as the *block*, which, by means of the hook, or eye, may be attached to any object. The complete device usually consists of two blocks, one attached to a fixed object and the other supporting the load. The rope connecting the two blocks, and by which they are worked and the load hoisted, is known as the *tackle*. The "pulley" is one of the "mechanical powers." Combinations of pulleys and blocks are used in order to gain a mechanical advantage in raising loads.

Block Indexing. With the multiple or "block" system of indexing, which is sometimes used in gear-cutting, a number of teeth are indexed at one time instead of cutting the teeth consecutively, and the gear is revolved several times before the teeth are all finished. For example, when cutting a gear having twenty-five teeth, the indexing mechanism is geared to index four

teeth at once, and, the first time around, six widely separated tooth spaces are cut. The second time around, the cutter is one tooth behind the spaces previously milled. On the third indexing, the cutter has dropped back another tooth, and the gear is finished (in this case) by indexing it around four times. The object of this method is to distribute the heat generated by the cutter (especially when cutting cast-iron gears of coarse pitch) more evenly about the rim of the gear, thus avoiding distortion due to local heating, and permitting higher speeds and feeds.

Blood-Albumin Glue. See Glues for Wood.

Bloodstone. A natural stone of small size sometimes used for burnishing small round work in the lathe. The bloodstone is mounted in a steel holder. It is an expensive tool, but ordinarily lasts for years.

Bloom. The products of a rolling mill may be classed as semifinished and finished. In the first class are blooms, slabs, billets, and sheet bars which have square, rhomboidal, or flat sections with rounded corners. A *bloom* has a square section and is about 6 inches square or larger.

Blooming Mill. See under Rolling Mills.

Blower. A blower may be defined as a low-pressure air compressor adapted for use in connection with forges, cupolas, gas plants, and blast furnaces. Blowers or compressors for this purpose are required to furnish air under pressures usually ranging from about two ounces to thirty pounds per square inch.

A *steel pressure fan or blower* is a special form of the ordinary ventilating fan adapted to higher pressures. The standard makes are commonly built for working pressures up to a maximum of about one pound per square inch, although special types may be constructed for considerably higher pressures. Blowers of this type are employed principally for forge and cupola practice. A *centrifugal blower* operates on the same principle as the pressure fan, but is designed for maintaining pressures up to from three to four pounds per square inch, thus considerably extending its field of operation beyond that of the steel pressure blower. A *rotary or positive pressure blower* is not a fan, although it is used for similar purposes. It is positive in its action and operates by displacement, the same as a piston compressor, although it is radically different in its construction. The maximum working pressure, with this type of blower, is limited to about ten pounds per square inch; and some of the standard makes of this type are not built for pressures exceeding five pounds per square inch. They are employed for purposes where a higher pressure is required than that which can be obtained economically by

means of a centrifugal blower; but the uses to which these two types are put, overlap one another to some extent. *Rotary blowers* have a wide field of application, being used for furnishing blast for cupolas, gas and oil burners, annealing and smelting furnaces, puddle furnaces, forges, gas plants, etc., as well as for vacuum cleaning, ash conveyors, pneumatic tube service, and many other special uses. When pressures exceeding those economically produced by the centrifugal and rotary blowers are required, and in some cases, for service for which these latter blowers could be used, the centrifugal compressor is employed, commonly known as the *turbo-compressor.*

Blower Pressures. The pressure used in connection with blower work is of three kinds, known as *dynamic, static,* and *velocity* pressure. The dynamic pressure is that due to the momentum of the air as it leaves the fan discharge, and acts only in the direction of flow. The static pressure is that produced by placing a resistance in the path of the air current, and, when confined in a duct, causes a uniform pressure in all directions, the same as the steam pressure within a boiler. It is evident that the dynamic pressure tends to drive the air through the fan outlet, while the static pressure tends to hold it back. The difference between these is called the velocity pressure, and is the working pressure which actually forces the air through the discharge opening in the casing. The relation between the velocity pressure and the velocity of flow which it produces, for air at a temperature of 60 degrees F., is expressed very nearly by the formula:

$$v = 66\sqrt{h},$$

in which, v = velocity of flow, in feet per second; h = velocity pressure, expressed in inches of water column. Ounces per square inch may be reduced to inches of water column by multiplying by 1.73, and inches of water column may be changed to ounces per square inch by multiplying by 0.58.

Blow, Force of. See Force of Blow.

Blow-Holes in Castings. Blow-holes are the result of an outrush of gas from the core or mold materials into the molten iron, at the time of solidification. If the solidification has proceeded so far that the outrushing gas or steam cannot bubble through it and escape through the vents which should be provided for the purpose, it will be imprisoned in the casting, forming one or more holes, according to the shape of the casting and the quantity of the escaping gas. These holes may not be apparent on the outside, and quite often occur in a location where they do no particular harm, but they are frequently located at some point where they are unsightly or greatly weaken the casting.

Blowing Engine. The term "blowing engine" is commonly used to designate blowers of the piston or reciprocating type used in connection with blast furnaces. These machines are simply air compressors designed for large volumes of air at comparatively low pressures. While superseded to a certain extent by the centrifugal compressor, blowing engines are still used in some of the largest plants in the country. Both steam and gas engines are employed for driving blowers.

Blow-out Circuit-Breaker. A device for automatically opening an electric circuit, so constructed that, when it opens under load, the resulting arc is instantly extinguished as the secondary contacts are parted, due to the force of a strong magnetic field automatically set up in the iron circuit of the blow-out magnet by the current being shunted through the blow-out coils and the secondary contact when the main brush breaks contact. The secondary contacts break contact immediately afterward.

Blue Glass. Blue glass is a development of the Bureau of Standards for protecting the eyes of furnace workers. This glass provides good contrast between the appearance of the furnace walls and the melt, and yet protects the observer against the dangerous ultraviolet radiation.

Blue Metal. An impure copper sulphide, containing some iron, which is obtained when smelting copper ores. When copper and some copper oxide are present the term "purple metal" is used.

Blueprinting. Blueprinting is a process of making copies of drawings that are made on transparent paper or tracing cloth. The tracing is used in a manner similar to that of the negative in making photographic prints, except that the tracing is a "positive," and the blueprints are negatives. The tracing with blueprint paper held tightly beneath it is exposed to the sunlight from 3 to 10 minutes, according to the intensity of light, or exposed to the brilliant electric lights in a blueprinting machine. After the exposure, the paper is washed thoroughly in cold water for about ten minutes and then hung up to dry. The print should show a deep blue color after washing and the lines should be clear white. If the color is pale blue, the print has not been exposed to the light for a sufficient length of time. If the lines of the drawing are not clear and white, the print has been over-exposed. An over-exposed blueprint can be improved upon by pouring a little of a solution made from one teaspoonful of *bichromate of potash* dissolved in one-half gallon of water, over the print while it is in the sink. The print must then be again washed with water before it is hung up to dry. The bichromate of potash solution

will improve the appearance even of blueprints that have not been over-exposed.

Blueprinting Machines. When a large number of blueprints are to be made, blueprinting machines are used for making prints without the aid of sunlight. These machines are generally provided with brilliant electric light, making it possible to produce prints at any time of the day or night.

The blueprint paper with tracings on top is passed by the light at a given rate of speed, which speed may be adjusted according to the requirements. Some machines are provided with an apparatus for washing and drying the prints after exposure.

Blueprint Marking Ink. Ordinary red writing ink with a little sal soda added will give clear distinct marks on blueprints. Very little sal soda is needed. Different grades of ink require different amounts, the right mixture being determined by adding the soda, a few grains at a time, until the ink begins to spread the least bit as it dries. A bright vermillion can be produced, which has the advantage of being visible as soon as it is placed on the blueprint.

Blue Vitriol. The commercial name applied to copper sulphate.

Board Drop-Hammer. See under Drop-hammers.

Board Measure. Board measure, as employed for measuring lumber, is based on the assumption that all boards are 1 inch thick. In order to obtain the number of feet board measure, multiply the length in feet, the width in feet, and the thickness in inches. For example, a board 2 inches thick, 10 feet long, and 9 inches wide would equal $10 \times \frac{3}{4} \times 2 = 15$ feet board measure. Board measure is frequently abbreviated B.M.

Board Measure of Logs. See Doyle Rule; Moore & Beeman Rule; Scribner Rule; St. Croix Rule.

Boiler Capacity Rating. The total heat transferred through the heating surfaces per hour is a measure of a capacity of a steam boiler. A nominal horsepower rating for stationary boilers, according to general practice, is based upon the square feet of heating surface. It is assumed that 10 square feet of heating surface is equivalent to one boiler horsepower under normal conditions. A boiler horsepower has been defined as the evaporation of 34.5 pounds of water per hour from a temperature of 212 degrees F. into steam at atmosphere pressure.

Boiler Code. This term is generally understood to refer to the rules and specifications for the construction of steam boilers and other pressure vessels, adopted by the American Society of Mechanical Engineers.

Boiler Efficiency. Efficiency of a boiler, including the furnace and grate, is the ratio of the heat absorbed by the boiler per pound of fuel fired, to the heat of perfect combustion per pound of fuel. The efficiency of the boiler alone is the ratio of the heat absorbed by the boiler per pound of fuel fired, to the heat actually developed in the furnace per pound of fuel. The general commercial practice is to base efficiency upon the combined efficiency of the boiler, furnace and grate.

Boiler Feed-Water Hardness. Hardness of boiler feed water is a condition caused by the presence of the incrusting solids, such as carbonates, sulphates, chlorides, and nitrates of lime and magnesia. The degree of hardness is a measure of the quantity of incrusting solids which boiler feed waters contain per gallon. The hardness may be temporary or permanent. *Temporary* hardness is caused by carbonates, and *permanent* hardness by sulphates, chlorides, and nitrates.

Boiler Feed-Water Heating. Boiler feed water is usually heated before discharging it into the boilers for two reasons: First, to overcome the effect of a rapid cooling of the plates, which is likely to result in unequal contraction and the formation of leaks at the joints, and also because a considerable volume of cold water fed into a boiler tends to reduce the steam pressure and thus makes it necessary to force the furnace for a time after feeding. Second, because feed-water heaters are nearly always arranged to utilize the waste gases from the furnace or the exhaust steam from the engines, and thus a considerable saving in fuel may be realized by their use.

The percentage of saving in fuel by the use of a feed-water heater may be obtained approximately by dividing the total rise in temperature by 11. For example, if the water enters the heater at a temperature of 50 degrees F. and leaves it at 200 degrees F., the total rise is $200 - 50 = 150$ degrees, and the percentage of saving is $150 \div$ by $11 = 13.6$. The proportion of the heat in the steam generated by the boiler, which is utilized in heating the feed water, may be found as follows: If it is assumed that the water is to be raised from 50 to 210 degrees F., the heat absorbed by 1 pound will be $210 - 50 = 160$ B.T.U. The latent heat of steam at atmospheric pressure is 966 B.T.U.; hence, $160 \div 966$ of the heat in each pound of exhaust steam is utilized in heating the feed water. This proportion is approximately one-sixth.

Boiler Feed-Water Impurities. Pure water is a chemical compound made up of two parts of hydrogen and one part of oxygen, by volume, and weighs 62.4 pounds per cubic foot at a temperature of 62 degrees F. It is never found in a pure state under natural conditions, as it absorbs large quantities of various impurities in its passage through the air, and in filtering through the earth before it reaches the wells or streams from which it is drawn for use in boiler plants or for other purposes. The impurities commonly found in boiler feed water may be classed under three heads, as follows: 1. Those causing the formation of scale; these impurities include calcium carbonate, calcium sulphate, magnesium carbonate, and magnesium sulphate. 2. Those having a corrosive action, such as sulphuric acid, carbonic acid, magnesium chloride, calcium chloride, and sulphate of iron. 3. Alkaline impurities which include sodium carbonate, sodium sulphate, sodium chloride, potassium carbonate, potassium sulphate, and potassium chloride. In addition to the impurities mentioned, various substances are held in suspension, such as organic matter, mud and oil.

Boiler Feed-Water Purification. The methods employed for the purification of feed water may be classed under three general heads as follows: 1. By filtering. 2. By heat. 3. By the use of chemicals. The character of the water will indicate whether one or more of these processes must be resorted to. Purification by mechanical means is employed only where the impurities are suspended in the water, as mud, sand, oil, vegetable matter, sewage, etc., and may be accomplished in three ways according to the substances present, and the available space for the apparatus. The methods commonly employed for this purpose are: Settling in large tanks; filtration; and skimming. Water from streams containing sawdust, chips, sticks, etc., requires simply a strainer over the suction pipe to the pump, if no other impurities are present.

Boiler Scale. The scale or incrustation formed in a boiler may be due to the precipitation of mineral substances or by the settling of mud or earthy matter held in suspension by the feed water. When the water is exceptionally bad, purifiers are often used, the water passing through the purifier before it enters the boiler. In this purifier, the temperature is raised until the water will no longer hold the carbonates and sulphates in solution, these being the most troublesome scale-forming substances; therefore, they are precipitated and remain in the purifier instead of being forced into the boiler. Various chemical substances are also introduced into boilers to combine with and dissolve the scale-forming material. One of the cheapest and

most effective of these substances is carbonate of soda. It is effective in preventing and removing scale resulting from both the carbonate and sulphate of lime. The best method is to connect the feed pump or injector to a soda tank so that at regular intervals a supply of soda can be introduced into the boiler. The proper amount should be determined in each case by experiment, and usually varies between one and two pounds per day for an average boiler. The lowest quantity that is effective should be used; if too much soda is used, it is apt to cause *priming*. The soda does not injure the boiler unless it is impure and contains acids.

Among the many substances introduced into boilers with the object of preventing the scale from forming into a hard mass, may be mentioned kerosene oil and petroleum. The former is generally considered preferable. It is claimed by those who have used kerosene that one quart per day for each 100 horsepower is sufficient to prevent the formation of scale, even though the water is very hard and impure. Kerosene is also effective for breaking up and loosening hard scale after it has formed. The most certain and effective remedy for the removal of scale which has been deposited on a boiler is by mechanical means, although chipping and scraping off the scale is often difficult and sometimes impossible, owing to the lack of room. The best method is to prevent the formation of the hard scale, and the easiest way of removing impurities is by opening the blow-off valve occasionally. A large part of the scale is naturally carried to the coolest part of the boiler (to the mud drum, if there is one), and it may be removed by blowing off the boiler while under steam pressure. The fact that many impurities are held in suspension and float as a scum on the water for some time before settling, has led to the use of the surface blow-out apparatus.

Boiling Point. The boiling point of a substance is the temperature at which it changes from a fluid to a gaseous form, under atmospheric pressure (14.7 pounds per square inch). The boiling point of water is 100 degrees C. (212 degrees F.). In order to cause the transformation from a fluid to a gaseous form, a certain amount of heat, known as the *latent heat of evaporation*, must be supplied to the liquid at the boiling point.

Bolster. Dies are usually held in position on the bed of a punch-press by means of a *bolster* or *diebed*, although large dies are often attached directly to the press bed. The principal functions of a bolster are: 1. That of supplying an adequate support for the die, and a holder to hold the die in its proper position to be engaged by the punch. 2. To furnish a means of attachment to the press. Bolsters are commonly made of cast iron,

cast steel, or machine steel. Large manufacturers seem to favor the use of semi-steel castings, or machine steel, rather than cast iron, for bolsters for certain classes of heavy work.

Bolt Cutters. The machines used for cutting the threads on bolts are known as "bolt cutters." A typical design is called a *single* bolt cutter because it has one spindle. Some bolt cutters have two, three, or four spindles and are known as *double, triple,* and *quadruple* bolt cutters, respectively. The thread is cut by means of a die-head attached to and revolved by the spindle of the machine. The bolt cutters having two or more spindles are used in preference to the single-spindle type where large quantities of bolts are to be threaded constantly. These machines operate on the same general principle as the single-spindle design. The spindles are parallel and each one has an independent carriage and vise so that, while a thread is being cut on one bolt, another bolt is being inserted in or removed from the vise of another carriage.

Some bolt cutters are equipped with a lead-screw so that the carriage will have a positive feeding movement when a thread is being cut, in order to prevent inaccuracy in the pitch of the thread. When a bolt cutter does not have a lead-screw, the feeding movement of the carriage is derived from the action of the dies upon the thread being cut. This method of feeding is satisfactory when cutting such threads as the United States Standard, the V-thread, or a Whitworth thread. When cutting square threads, however, or those of special form, or when threading long work where the cumulative error becomes important, a lead-screw is necessary.

Bolt, Expansion. See Expansion Bolt.

Bolt Forging Machines. Upsetting and heading machines of modern design are divided into two general classes: stop-motion and continuous-motion headers. The stop-motion headers have the greatest range, and are primarily used for heading bolts, but are also used for all kinds of upset forgings. The continuous-motion headers are used only for heading rivets, carriage bolts, and short lengths of hexagon- and square-head machine bolts; they produce these parts at a much faster rate than is possible with a stop-motion header, but their range of work is limited.

Bolt Forging, Origin. The bolt and nut industry in America was started in a very small way in Marion, Conn., in 1818. In that year Micah Rugg, a country blacksmith, made bolts by the forging process. The first machine used for this purpose was a device known as a heading block, which was operated by a foot treadle and a connecting lever. The connecting lever held the

blank while it was being driven down into the impression in the heading block by a hammer. The square iron from which the bolt was made was first rounded, so that it could be admitted into the block. At first Rugg only made bolts to order, and charged at the rate of sixteen cents apiece. This industry developed very slowly until 1839, when Rugg went into partnership with Martin Barnes; together they built the first exclusive bolt and nut factory in the United States in Marion, Conn. The bolt and nut industry was started in England in 1838 by Thomas Oliver, of Darlson, Staffordshire. His machine was built on a somewhat different plan from that of Rugg's, but no doubt was a further development of the first machine; Oliver's machine was known as the "English Oliver."

Bolt Head Standards. American Standard bolt heads are made in two series known as the Regular Series and the Heavy Series. Regular bolt heads (and nuts) are for general use. Heavy bolt heads (and nuts) are for use where a larger bearing surface is necessary, as, for example, where the clearance between the bolt and hole is larger or a greater wrench bearing surface is considered essential. In both the regular and heavy series, there are unfinished, semi-finished, and finished grades.

Regular Bolt Heads, Unfinished: The width across the flats of square and hexagon heads equals $1\frac{1}{2} \times$ bolt diameter, adjusted to sixteenths. Unfinished heads are not machined on any surface.

Regular Bolt Heads, Semi-Finished: The width across the flats of square and hexagon heads equals $1\frac{1}{2} \times$ bolt diameter, adjusted to sixteenths. Semi-finished heads are machined under the head only.

Regular Bolt Heads, Finished: Finished bolt heads and nuts are made to the same dimensions as semi-finished. The surfaces, however, have been so treated as to provide a special appearance. The finish desired on all non-bearing surfaces of finished bolt heads and nuts should be specified by the purchaser.

Heavy Bolt Heads, Unfinished: The width across the flats of square and hexagon forms equals $1\frac{1}{2} \times$ bolt diameter $+ \frac{1}{8}$ inch, adjusted to sixteenths.

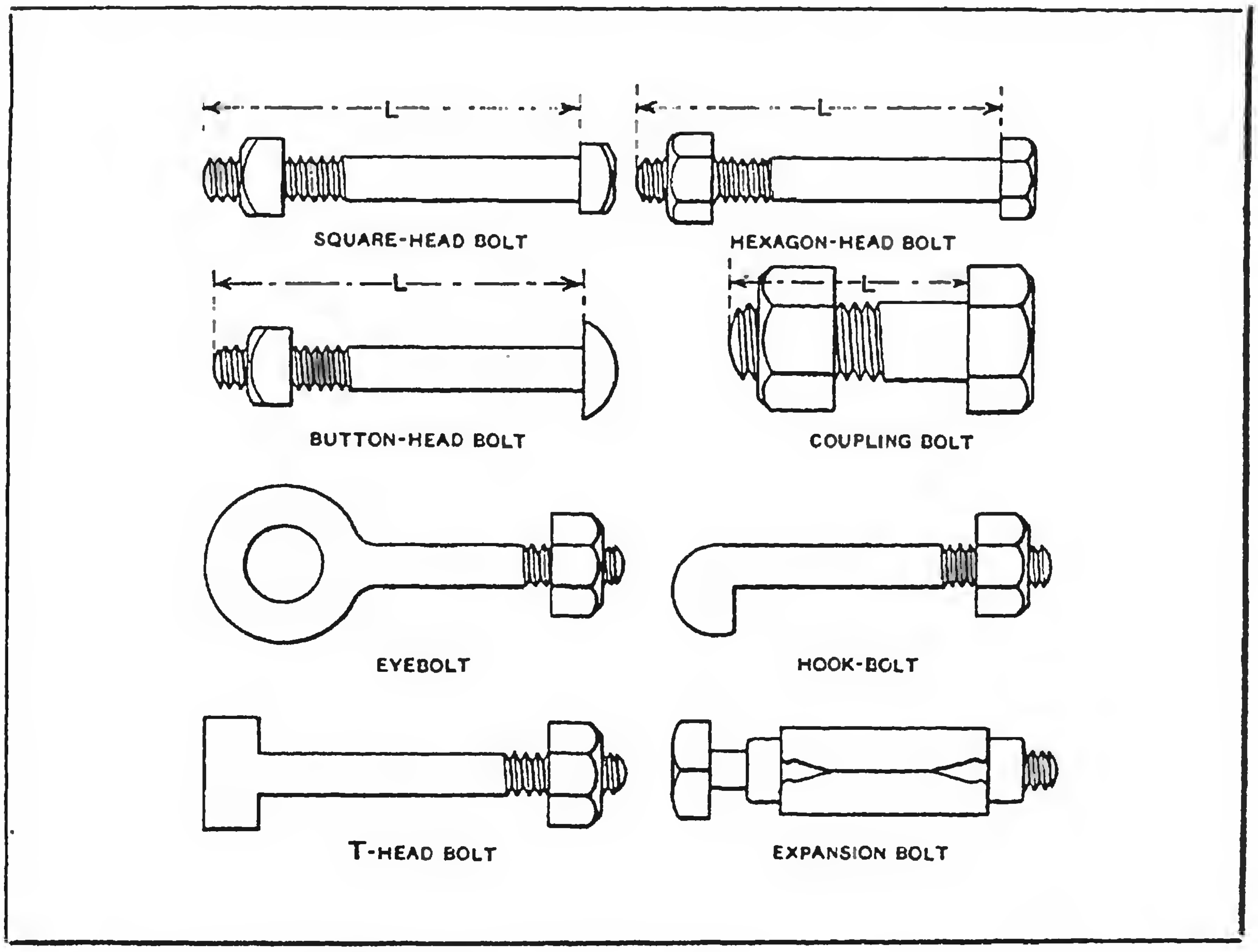
Heavy Heads, Semi-Finished and Finished: The width across flats of square and hexagon forms equals $1\frac{1}{2} \times$ bolt diameter $+ \frac{1}{8}$ inch, adjusted to sixteenths.

Tolerance: The tolerance for width across flats of square and hexagon heads, equals $0.050 \times$ nominal bolt diameter. The original standard which was adopted by the American Standards Association in 1933, was revised in 1941. See also Nut Standardization.

Bolt Oil. This is a viscous neutral oil used for thread cutting. It has a gravity of about 30 degrees Baume and a viscosity of about 220.

Bolt-Pointing Machines. The "bolt pointer" is a machine used for rounding or pointing the ends of bolts preparatory to cutting the thread. As the bolt leaves the "header" or machine which forms the head, the ends are generally irregular, resulting from the action of the shear in cutting the stock; this irregular edge makes it difficult to start the thread cutting die, so ordinarily a pointing tool is used which is so formed as to produce a rounding end. These pointing machines have a spindle which carries the cutter head, and a vise for holding the bolt to be pointed.

Bolts. The difference between a bolt and a screw, according to the generally accepted meaning of the terms, is that nuts are used on bolts, whereas screws are inserted into tapped holes; there are exceptions, however, to this general classification. A bolt has a solid head on one end and ordinarily one or two nuts on the other, which bind together whatever parts are to be held. A bolt may pass through a "clearance hole" or one that is slightly larger than the bolt diameter, or it may be accurately fitted to the hole so that the body of the bolt will prevent lateral



Standard and Special Forms of Bolts

movement of the parts instead of relying entirely upon the friction resulting from the pressure of the nut. The illustration shows standard bolts with the several types of heads and some special forms of bolts.

Eyebolt: The eyebolt is so named because the head forms a loop or "eye" which may be used in different ways. Eyebolts are often attached to heavy machine parts to provide means for lifting them when making repairs, etc., the eye of the bolt being engaged by the hook of a crane or hoist.

Hook-bolt: The hook-bolt is a special form of bolt having a hook-shaped head instead of one that is square or hexagonal. Such a bolt may be used when the part to be clamped is too narrow for drilling a bolt hole through it, or because such a hole would weaken the part excessively.

T-head Bolt: The T-head bolt is extensively used for clamping castings and forgings to various kinds of machine tools. The T-shaped heads of the bolts engage T-slots which extend along the table of the machine.

Expansion Bolt: When a through bolt cannot be used for attaching a pipe hanger, bracket, or other part, to a wall or ceiling of brick or concrete, what are known as *expansion* bolts are often used. The body of an expansion bolt is divided and the arrangement is such that, when the head of the bolt is turned, the sections forming the body of the bolt are forced outward and against the wall of the hole which has been drilled into the brick, concrete, or stone, as the case may be. Bolts of this type are made in quite a variety of designs. The nominal size represents the diameter of the bolt proper and not the diameter of the casing or expansion member.

Bolt Stresses. The initial tensional stress in a tightened bolt or stud holding a part subjected to pressure may or may not be increased by that pressure before the initial tension of the bolt is exceeded. When bolts are more elastic than the material compressed, as when flanges are bolted together without a yielding packing between, the stress in the bolts equals either the initial stress (due to tightening the nut) or the force applied, depending upon which is greater. If the material compressed is more elastic than the bolts, as when an elastic packing is compressed between flanges, the stress in the bolts equals the initial stress plus the force applied.

Bonderizing. "Bonderizing" is a surface treatment for steel developed by the Parker Rust Proof Company and involving the use of "Bonderite" phosphate coating chemicals. The result is a chemical conversion of the metallic surface to a non-metallic phosphate coating composed of microscopic crystals integral

with the metal. This crystalline coating provides a durable base for paint finishes by preventing corrosion of the underlying metal.

Bonding Processes for Grinding Wheels. By the use of different abrasives, grinding wheels can be produced which are adapted to many different purposes. The important properties of an abrasive are hardness, toughness, absence of impurities, uniformity, and fracture or sharpness. The nature or characteristics of a grinding wheel can also be changed by using different bonds, the bond being the adhesive substance which holds the abrasive grains together in the form of a wheel. The three most important bonding processes are known as the vitrified, silicate, and elastic processes, and these names are applied to the wheels. For instance, a wheel made by the vitrified process is commonly referred to as a vitrified wheel, etc. Among other processes which are employed may be mentioned the rubber or vulcanite process, the celluloid process, and the oil process.

In the *vitrified process* the abrasive is mixed with feldspar and clay; the mixture being heated to a high temperature in kilns until the clay fuses and bonds the ingredients. The wheels resulting are uniformly of open porous structure, and adapted to all kinds of general work. About 80 per cent of the wheels made are of this type.

In the *silicate process* the abrasive is mixed with silicate of soda; the mixture being subjected to a comparatively low baking temperature, around 500 degrees F., for from 20 to 80 hours. The wheels are smooth cutting and especially adapted for tools requiring a sharp edge.

In the *elastic process* the abrasive is usually bonded with shellac; the mixture being baked at a low temperature, around 300 degrees F., for a few hours. Very thin wheels can be made by this process and they are adapted for cutting off metal, tubing, wire, etc. An extremely high finish can also be obtained by the use of these wheels.

In the *rubber (vulcanite) process* the abrasive is mixed with pure rubber, to which is added sulphur as a vulcanizing agent, and heated under pressure to a temperature sufficient to vulcanize the rubber. Very thin wheels can be made by this process, and as they have a strong bond they are especially adapted for the cutting of narrow slots and grooves.

Bone Black. A material made by heating bones to a high temperature for several hours and grinding the residue. It contains a large amount of calcium phosphate and carbon, has a specific gravity of 2.68, and grinds in 50 per cent of oil. It is used for paints for the protection of iron and steel against corrosion, and to replace carbon-black and lamp black.

Bontempi Process. A method of producing a coating on iron or steel to protect it from the corrosive effects of the atmosphere, known as the Bontempi process, consists of heating the articles with hydrogen to a low red heat in a retort, then admitting a small quantity of gasoline, and finally passing steam or fumes of zinc or of some heavy hydrocarbon, such as tar or pitch, over the articles.

Bonus Wage System. The task or bonus system of wage payment, introduced by H. L. Gantt, is based on the principle of increasing the pay in a certain ratio as the time of completing the job is decreased, the rate of increase in compensation depending upon the percentage of time saved. The system resembles the premium wage system very closely. Each workman always receives his regular hourly rate, a definite standard task is scientifically determined for each worker, and he receives from 50 to 100 per cent extra wages for performing this task within the time limit allowed. If he finishes the task in less than the specified time limit, he is paid his hourly pay for the time actually used for the task, as well as the bonus; he uses the time saved for a new task. The foreman is given a bonus for each man under him who earns a bonus, and receives an additional bonus if all of the men working for him earn a bonus.

Booster. A booster is a generator inserted in series in a circuit to change its voltage. It is generally driven by an electric motor and may be either for alternating or direct current. Alternating-current boosters are mostly used in connection with synchronous-booster converters, and to a certain extent in connection with transmission systems for controlling the voltage of different plants that are operating in parallel on the same system. Direct-current boosters are used in railway power stations to raise the potential of the feeders extending to distant points of the system, and also for storage battery charging and regulation. Where there are a number of lighting feeders connected that run at full load for only a short time each day, it is generally found economical to install boosters rather than to invest in additional feeder copper. Boosters may be non-automatic or automatic in their variation of voltage. The former are used generally for charging batteries, and occasionally for assisting battery discharge, while the latter are used for line-drop compensation and for the purpose of causing instantaneous charge and discharge of a battery on systems supplying energy to loads that fluctuate widely and rapidly in the power demand.

Borax. Sodium pyroborate and sodium biborate, a combination of sodium, boron, and oxygen, is known commercially as

borax. The commercial use of borax is as a flux for soldering and welding. Fused borax dissolves many metallic oxides, forming with them chemical combinations. The use of borax as a flux depends upon the facts that solder adheres only to the surface of an untarnished metal, and that borax placed on the surface of the metal and heated by the soldering iron to the fusing point, removes any superficial film of oxide, and thereby makes it possible for the solder to adhere to the metal surface. Borax is obtainable in two forms: common or prismatic borax, and jewelers' or octahedral borax. The crystals of octahedral borax fuse more easily than those of the prismatic form and are, therefore, preferable to use as a flux in soldering or welding. Borax is found in large quantities in California, but the main supply is obtained from Italy.

Boring Machines. Boring machines may be divided into two general classes, *vertical* and *horizontal.* The standard designs of these machines are not intended exclusively for boring, and very often boring constitutes a small part of the work. For instance, vertical boring machines are very generally used for turning cylindrical, flat, and tapering surfaces, whereas many machines of the horizontal type may be used for drilling, milling, and flange facing. Because of this fact, the names, "vertical boring and turning machines" and "horizontal boring, drilling, and milling machines," are frequently applied to these two classes of machine tools.

Vertical Boring Machine: The vertical boring and turning machine or "mill" belongs to the lathe family, and is very efficient for work within its range. This type of machine is designed for turning and boring work which, generally speaking, is quite large in diameter in proportion to the width or height. The part to be turned and bored is held to the machine table either by clamps or in chuck jaws attached to the table. When the machine is in operation, the table, which has a vertical spindle, revolves and the turning or boring tools remain stationary, except for the feeding movement. Very often more than one tool is used at a time.

Modern vertical boring mills of medium and large sizes are equipped with two tool-heads, because a great deal of work done on a machine of this type can have two surfaces operated upon simultaneously. On the other hand, small mills have a single head, and ordinarily the tool-slide, instead of having a single tool-block, carries a turret in which different tools can be mounted. These tools are shifted to the working position as they are needed, by indexing the turret the same as on a regular turret lathe. Frequently, all the tools for machining

a part can be held in the turret, so that little time is required for changing from one tool to the next. Some large machines equipped with two tool-heads also have a turret on one head instead of the regular tool-block.

Horizontal Boring Machines: On machines of this class, the bed and cutter-driving spindle are horizontal. These machines are employed principally for boring, drilling, or milling, whereas the vertical design is especially adapted to turning and boring. The horizontal type is also used for turning or facing flanges or similar surfaces when such an operation can be performed to advantage in connection with other machine work on the same part.

The floor type of horizontal boring, drilling, and milling machine, is intended for boring heavy parts such as the cylinders of large engines or pumps, the bearings of heavy machine beds, and similar work. This machine can also be used for drilling and milling, although it is intended primarily for boring, and the other operations are usually secondary. This design is ordinarily referred to as the "floor type," because the work table is low for accommodating large heavy castings. The spindle which drives the boring-bar, and the spindle feeding mechanism, are carried by a saddle. This saddle is free to move vertically on the face of a column which is mounted on transverse ways extending across the end of the main bed. This construction permits the spindle to move vertically or laterally (by traversing the column) either for adjusting it to the required position or for milling operations. The spindle also has a longitudinal movement for boring. There is usually an outer bearing for supporting the boring-bar.

Boring Machines, Origin. The first boring machine was built by John Wilkinson, in 1775. Smeaton had built one in 1769 which had a large rotary head, with inserted cutters, carried on the end of a light, overhanging shaft. The cylinder to be bored was fed forward against the cutter on a rude carriage, running on a track laid in the floor. The cutter head followed the inaccuracies of the bore, doing little more than to smooth out local roughness of the surface. Watt's first steam cylinders were bored on this machine and he complained that one, 18 inches in diameter, was 3/8 inch out of true. Wilkinson thought of the expedient, which had escaped both Smeaton and Watt, of extending the boring-bar completely through the cylinder and giving it an out-board bearing, at the same time making it much larger and stiffer. With this machine cylinders 57 inches in diameter were bored which were within 1/16 inch of true. Its importance can hardly be overestimated as it insured the com-

mercial success of Watt's steam engine which, up to that time, had not passed the experimental stage.

Boron. A non-metallic chemical element, the symbol of which is B. The atomic weight of boron is 11.0; the specific gravity, 2.6; and the melting point, 2200 degrees C. (about 4000 degrees F.). It is found in nature in the form of boracic acid and in borax and boracite. It has a strong affinity for oxygen and is, therefore, one of the best deoxidizers known. For this reason it is employed when casting copper, as it is possible by its use to obtain castings which are sound, free from blow-holes, and having high electrical conductivity. See also Adamantine Boron.

Boron-Bronze. Boron-bronze is an alloy composed of aluminum and copper, with a small percentage of boron. The addition of boron increases the density of the alloy, and makes it stronger and tougher than ordinary aluminum bronze. It is probable that it is not the percentage of boron actually present in the alloy that exerts so favorable an influence; but more likely the improved qualities are due to the deoxidizing influence of boron in the molten metal.

Boronized Copper. Prior to the use of boron, it was practically impossible to cast copper of mechanical soundness and of high electrical conductivity, on account of the porous metal that was obtained. Boron has a high affinity for oxygen, nitrogen, and oxygen-containing gases which cause the difficulty in copper casting, and since boron has no affinity for copper, it is a natural deoxidizer for copper. The boronizing process delivers a good metal, and the production of a good casting depends upon the same factors as in other metals. The boronized copper shrinks about ¼ inch to the foot. Boronized copper castings have a tensile strength of 25,000 pounds per square inch, an elastic limit of 11,500 pounds per square inch, an elongation of 48 per cent, a reduction in area of 75 per cent, and under ordinary foundry conditions an electrical conductivity of 90 (silver = 100).

Bort. Bort is an inferior variety of diamond which is used in the industries for truing soft grinding wheels and for making diamond dies for wire drawing and similar purposes. It is not as hard as the variety of diamond known as the *carbon* or *black diamond,* and is considerably lower in price; but it is not as economical to use as the black diamond for truing hard grinding wheels. While the bort is a semi-transparent stone known as an "imperfect brilliant," and, therefore, useless as a precious stone, it is very useful as an abrasive agent. It generally occurs in small spherical masses of grayish color. In its commercial

usage, the term "bort" is often extended to all small and impure diamonds and crystalline fragments of diamonds which cannot be used as gems. A large proportion of these stones come from South Africa. All classes of diamonds are invariably weighed in carats and in the subdivision ½, ¼, ⅛, 1/16, 1/32 and 1/64 of a carat. 1 carat (International system) = 3.086 grains = 0.200 gram; 1 ounce troy = 155.5 carats.

Bower-Barff Process. This is a process for protecting iron and steel parts against the corrosive effect of air or moisture by oxidizing the surfaces. In this process, the parts to be treated are heated to a temperature of about 1650 degrees F. in a closed retort, for about forty minutes; then superheated steam is led into the retort for twenty minutes and a coating of a mixture of black and red oxides of iron is formed; producer gas is now substituted for the steam and permitted to act upon the articles for about the same length of time. If the coating formed in this manner is not sufficiently thick, the operations may be repeated several times. Paraffin or some other oil is afterward applied to the articles. This gives them a heavy black coating, consisting essentially of magnetic oxide of iron, and gives a durable finish. A number of processes have been developed on the basis of the Bower-Barff process which differ in a number of details, but which are based on the same fundamental principle of providing a protective coating of oxide on the iron or steel.

Bow Pencil and Pen. The bow pencil is used for drawing small circles as it is a small instrument and easier to manipulate than the ordinary dividers or compass. The bow pen is of similar construction, the only difference being that it is fitted with the blades of a drawing pen instead of a socket for carrying a pencil point.

Box-Jigs. A great many parts must be drilled on different sides and, frequently, the work is very irregular in shape, so that a jig which is made somewhat in the form of a box, and encloses the work, is very essential, as it enables the guide bushings to be placed on all sides and also makes it comparatively easy to locate and securely clamp the part in the proper position for drilling. As a rule the piece to be drilled can be inserted only after one or more covers or leaves have been swung out of the way.

Box-Tools. The box-tool is a type which is equipped with some form of back-rest opposite the turning tool for supporting the work; it usually encloses or surrounds to some extent the part being turned, for which reason it is known as a *box-tool.*

Tools of this type are extensively used on turret lathes and screw machines for turning parts from bar stock. There are many different designs.

Boyle's or Mariotte's Law. The volume of a gas decreases in the same ratio as the pressure upon it is increased, provided the temperature remains constant. This law is known as Boyle's or Mariotte's law. This law may also be expressed as follows: The product of the pressure times the volume is constant for constant temperatures. Hence, if $P =$ the pressure on a gas the volume of which is V, and P_1 is the pressure when the same gas occupies a volume V_1, then:

$$P \times V = P_1 \times V_1.$$

Bradley Process. A method for producing a coating on iron or steel to protect it from the corrosive effects of the atmosphere, in which the articles to be treated are heated in a retort with hydrogen gas to a low red heat, after which a small quantity of gasoline is permitted to enter. The articles are then left in the furnace for an hour, or longer if the coating is not sufficiently heavy, after which they are allowed to cool, and a coating of paraffin or linseed oil applied, which gives them a fine black color and affords additional protection.

Brake Horsepower. The brake horsepower is the power of a steam engine or other power generating machine delivered from the flywheel shaft or main driving shaft of the machine. The power expended in overcoming frictional resistance in the engine itself, is not included in the brake horsepower. In order to determine the brake horsepower, a friction brake or dynamometer is applied to the rim of the flywheel, or to the shaft. The *Prony brake* is one of the simplest types of dynamometers to use for this purpose. (See also, Horsepower.)

Brakes for Bending. A bending brake is a form of press used in sheet-metal work for forming strips and plates. Brakes are made in both hand-operated and power-operated types. As compared with other presses for forming sheet metals, brakes are wide between the housings and are designed for holding long, narrow forming edges or dies for giving the flat stock whatever shape is required. Brakes are used extensively in the manufacture of various kinds of metal furniture, and for miscellaneous sheet metal bending and forming operations.

Branch Pipe. This is a very general term used to signify a pipe, either cast or wrought, that is equipped with one or more branches. Such pipes are used so frequently that they have acquired common names, such as tees, crosses, side or back

outlet elbows, manifolds, double-branch elbows, etc. The term *branch pipe* is generally restricted to such as do not conform to usual dimensions.

Brass. Brass is an alloy composed mainly of copper and zinc and sometimes containing small percentages of lead and iron. When zinc is present in small percentages, say about 10 per cent, the color of brass is nearly red, and the alloy is known as "red brass." An alloy containing about 20 per cent of zinc is more yellow, and a number of metals with percentages of zinc around this value resemble gold, and are known as "Dutch" metal, "Mannheim gold," and various other trade names. Ordinary brass for machine construction, piping, etc., contains from 30 to 40 per cent of zinc. A number of the brasses are known by special names, such as admiralty metal, Muntz metal, manganese-bronze (which is not a bronze, but a brass composition, bronze being an alloy in which copper and tin are the basic metals), naval brass, etc.

As used in the industries, brass castings usually contain 65 per cent of copper and 35 per cent of zinc. So-called "low" brasses, which are especially suitable for hot-rolling, contain from 37 to 45 per cent of zinc. The "high" brasses, which are used for cold-rolling and drawing, contain from 30 to 40 per cent of zinc. If lead is present to an amount exceeding 0.1 per cent, the ductility of brass is decreased, and sheet brass intended for drawing should be as free from lead as possible. Brasses that must be machined, however, may contain up to 2 per cent of lead to advantage, as in that case they can be turned at high speed and a better finish obtained. Small percentages of antimony, arsenic, or bismuth in brass make it brittle and cause it to crack when rolled or drawn. In order to make brass resist the corrosion due to salt water, an addition of about 1 per cent of tin has been found advantageous.

Brass Alloys for Castings. The compositions which follow are all S.A.E. Standard and are given in percentages. Typical applications of the different alloys in the automotive industry are cited, and physical properties are given based upon standard test bars cast into sand molds and used without machining.

No. 40—Red Brass Castings: Red brass is used for water-pump impellers, fittings for gasoline and oil lines, small bushings, small miscellaneous castings. This is a free-cutting brass with good casting and finishing properties.

Composition of No. 40: Copper, 84.0 to 86.0; tin, 4.0 to 6.0; lead, 4.0 to 6.0; zinc, 4.0 to 6.0; iron, max. 0.30; nickel, max., 1.0; aluminum, max., 0.005; silicon, max., 0.005 per cent.

Physical Properties: Tensile strength, 30,000 pounds per square inch; elongation in 2 inches, 20 per cent.

No. 41—Yellow Brass Castings: Yellow brass is used for radiator parts, fittings for water-cooling systems, battery terminals, miscellaneous castings. This alloy is intended for commercial castings when cheapness and good machining properties are essential.

Composition of No. 41: Copper, 65.0 to 70.0; tin, max., 1.5; lead, 1.5 to 3.75; iron, max., 0.75; aluminum, max., 0.30 per cent; zinc, balance.

Physical Properties: Tensile strength, 30,000 pounds per square inch; elongation in 2 inches, 20 per cent.

Nos. 43, 430 A, and 430 B—Manganese Bronze Castings: These alloys are used for their strength, corrosion resistance, and casting properties as brackets, shafts, gears and structural members.

Composition of No. 43: Copper, 55.0 to 60.0; tin, max., 1.0; lead, max., 0.40; iron, 0.40 to 2.0; nickel, max., 0.50; aluminum, 0.5 to 1.5; manganese, max., 1.5 per cent; zinc, balance.

Composition of Nos. 430 A and 430 B: Copper, 60.0 to 68.0; tin, max., 0.20; lead, max., 0.20; iron, 2.0 to 4.0; nickel, max., 0.50; aluminum, 3.0 to 7.5; manganese, 2.5 to 5.0 per cent; zinc, balance.

Physical Properties of No. 43: Tensile strength, 65,000 pounds per square inch; yield strength, 25,000 pounds per square inch; elongation in 2 inches, 20 per cent.

Physical Properties of No. 430 A: Tensile strength, 90,000 pounds per square inch; yield strength, 45,000 pounds per square inch; elongation in 2 inches, 20 per cent.

Physical Properties of No. 430 B: Tensile strength, 110,000 pounds per square inch; yield strength, 60,000 pounds per square inch; elongation in 2 inches, 12 per cent.

Brass, Clock. See Clock Brass.

Brass Coloring. Brass and copper may be given many different colors by the use of the proper chemical solutions.

Yellow or Orange Colors: Polished brass pieces can be given a color from a golden yellow to an orange, by immersing them for the correct length of time in a solution composed of 5 parts of caustic soda to 50 parts of water, by weight, and 10 parts of copper carbonate. When the desired shade is reached, the work must be well washed with water and dried in sawdust. Golden yellow may be produced with the following: Dissolve 100 grains of lead acetate in 1 pint of water and add a solution of sodium

hydrate until the precipitate which first forms is redissolved and then add 300 grains of red potassium ferricyanide. With the solution at ordinary temperatures, the work will assume a golden yellow, but heating the solution darkens the color until, at 125 degrees F., it has changed to a brown. A pale copper color can be given brass by heating it over a charcoal fire, with no smoke, until it turns a blackish brown, then immersing in a solution of zinc chloride that is gently boiling, and finally washing thoroughly in water. Dark yellow can be obtained by immersing for five minutes in a saturated solution of common salt containing some free hydrochloric acid which has as much ammonium sulphide added as the solution will dissolve.

Rich Gold Colors: A rich gold color can be given brass by boiling it in a solution composed of 2 parts of saltpeter; 1 part of common salt; 1 part of alum; 24 parts of water, by weight; and 1 part of hydrochloric acid. Another method is to apply to the work a mixture composed of 3 parts of alum; 6 parts of saltpeter; 3 parts of sulphate of zinc; and 3 parts of common salt. The work is then heated over a hot plate until it becomes black, and then washed with water, rubbed with vinegar, and again washed and dried. Still another solution is made by dissolving 150 grains of sodium thiosulphate in 300 grains of water and adding 100 grains of an antimony-chloride solution. After boiling for some time, the red-colored precipitate must be filtered off, well washed with water, and added to 4 pints of hot water. Then add a saturated solution of sodium hydrate and heat until the precipitate is dissolved. Immerse the brass articles in the latter solution until they have attained the correct shade. If left in too long they will be given a gray color.

Black Finish on Brass: There are as many different processes and solutions for blackening brass as there are for browning, and consequently, only a few can be given. Trioxide of arsenic, white arsenic, or arsenious acid are different names for the chemical that is most commonly used. Its use can be traced back to the fifth century and it is the cheapest chemical for producing black on brass, copper, nickel, German silver, etc. It has a tendency to fade and a much greater tendency if not properly applied, but a coat of lacquer will preserve it a long time. A good black can be produced by immersing work in a solution composed of 2 ounces of white arsenic and 5 ounces of cyanide of potassium in 1 gallon of water. This should be boiled on a gas stove, in an enamel or agate vessel, and used hot. Another cheap solution is composed of 8 ounces of sugar of lead; 8 ounces of hyposulphate of soda; and 1 gallon of water. This must also be used hot and the work afterward lacquered to prevent fading.

When immersed, the brass first turns yellow, then blue, and then black, the latter being a deposit of sulphide of lead.

White Coating: The white color or coating that is given to such brass articles as pins, hooks and eyes, buttons, etc., can be produced by dipping them in a solution made up as follows: Dissolve 2 ounces of fine grain silver in nitric acid, then add 1 gallon of distilled water and put into a strong solution of sodium chloride. The silver will precipitate in the form of chloride and this must be washed until all traces of acid are removed. Testing the last rinse water with litmus paper will show when the acid has disappeared. Then mix this chloride of silver with an equal amount of potassium bitartrate (cream of tartar) and add enough water to give it the consistency of cream. The work is then immersed in this mixture and stirred around until properly coated, after which it is rinsed in hot water and dried in sawdust.

Gray Colors: A solution of 1 ounce of arsenic chloride in 1 pint of water will produce a gray color on brass, but if the work is left in too long it will turn black. The brass objects are left in the bath until they have assumed the correct shade, and then are washed in clean warm water, dried in sawdust, and finally in warm air. A dark gray color that can be made lighter by scratch-brushing can be obtained by immersing the work in the following solution: 2 ounces of white arsenic oxide; 4 ounces of commercially pure (c.p.) hydrochloric acid; 1 ounce of sulphuric acid; and 24 ounces of water. A steel gray can be produced with the following: 20 ounces of arsenious oxide; 10 ounces of powdered copper sulphate; 2 ounces of ammonium chloride; and 1 gallon of hydrochloric acid. After mixing, this should stand for one day. A 5-per-cent solution of platinum chloride in 95 per cent of water will also produce a dark gray color, if it is painted on and the brass is warmed. Weaker solutions will make the color lighter. Copper can also be colored, but the platinum does not adhere as firmly to the surface as it does on brass. A coating of lacquer is required to make it permanent. By smearing the work with a mixture of 1 part of copper sulphate and 1 part of zinc chloride in 2 parts of water, and drying this mixture on the brass, with heat, a dark brownish color is obtained. If desirous of immersing the work, a weaker solution could be used. The color is changed very little by exposure to light.

Lilac Colors: The lilac shades can be produced on yellow brass by immersing the work in the following solution when heated to between 160 and 180 degrees F. Thoroughly mix 1 ounce of chloride, or butter, of antimony in 2 quarts of muriatic acid, and then add 1 gallon of water.

Violet Colors: A beautiful violet color can be produced on polished brass with a mixture of two solutions. First, 4 ounces of

sodium hyposulphite is dissolved in 1 quart of water, then 1 ounce of sugar of lead is dissolved in another quart of water, and the two are well stirred together. By heating this mixture to 175 degrees F. and immersing the work the correct length of time, it takes on the violet color. The work first turns a golden yellow and then gradually turns to violet. If left a longer time, the violet will turn to blue and then to green. Thus, this same preparation can be used for all of these colors by correctly limiting the time that the work is immersed.

Green Colors: When left to the natural action of the atmosphere, or ageing, most of the brasses and bronzes first turn green, especially if near the ocean where the moisture from the salt-water attacks the metal. This green color gradually darkens and then turns brown, and finally black. One solution that will produce the verde antique, or rust green, is composed of 3 ounces of crystallized chloride of iron; 1 pound of ammonium chloride; 8 ounces of verdigris; 10 ounces of common salt; 4 ounces of potassium bitartrate; and 1 gallon of water. If the objects to be colored are large, this can be put on with a brush and several applications may be required to give the desired depth of color. Small work should be immersed, the length of time it is immersed governing the lightness or darkness of the color. After immersion, stippling the surface with a soft round brush, dampened with the solution, will give it the variegated appearance of the naturally aged brass or bronze. Another solution that will give practically the same results is composed of 2 ounces of ammonium chloride; 2 ounces of common salt; 4 ounces of aqua ammonia; and 1 gallon of water. The work may have to be immersed or painted several times to give it the desired coating, and, after washing and drying, it should be lacquered or waxed.

Brown Colors: Many different shades of brown can be produced and many different chemicals are used to form solutions or pastes for this purpose. In these mixtures, liver of sulphur, either potassium sulphide or sodium sulphide, is one of the most commonly used chemicals. One-fourth ounce of liver of sulphur in 1 gallon of water will give bronze a brown color, when used cold, but, if heated, it is more effective. The depth of the color is governed by the length of time that the work is immersed. If left in too long, however, it becomes black and if too much liver of sulphur is used the color will also be black. Copper is turned black even with the weak solutions. To set the color, it should afterwards be immersed in water containing a small amount of sulphuric or nitric acid. Brass is not attacked by this solution, but if caustic potash is added it causes the liver of sulphur to color the brass. Then, 2 ounces of liver of sulphur should be added to 1 gallon of water and from 2 to 8 ounces of caustic

potash, according to the shade of brown that is desired; the more potash the darker will be the color. A solution composed of ½ ounce of potassium sulphide in 1 gallon of water will produce a gray or greenish color on brass, when cold, but, when heated to 100 degrees F., it produces a light brown; at 120 degrees, a reddish brown; at 140 degrees, a dark brown; and at 180 degrees, a black color.

Bronze Color: The barbedienne bronze, or brown, color can be produced on cast brass or bronze by immersing in a solution made by dissolving 2 ounces of golden sulphuret of antimony and 8 ounces of caustic soda in 1 gallon of water. The work must be properly cleaned beforehand and afterward scratch-brushed wet, with a little pumice stone applied when brushing. It must then be well washed and dried in sawdust. A second immersion in a solution of one-half the above strength will have a toning effect, and the work must again be washed and dried. The high light can be made to show relief by rubbing the object with pumice-stone paste on a soft rag. A dead effect can be produced by immersing in a hot sulphuret of antimony solution for ten or fifteen seconds, then rewashing and immersing in hot water for a few seconds, and drying in sawdust. The work should be lacquered to preserve the tones, and waxed when the lacquer has become dry and hard. This brown color can be darkened by a five-seconds immersion in a cold solution of 8 ounces of sulphate of copper in 1 gallon of water. Some other processes use two solutions, the first of which is heated and the second used cold, after which the work is rinsed in boiling water.

Brass Cleaning Before Coloring: Cleaning brass is of the utmost importance before subjecting it to a chemical coloring process. Several acid dips will remove the films which form on brass, bronze and copper, and leave the bright clean metal with its original smooth surface. Work that will stand heating can be heated to a dull red and then plunged into dilute sulphuric acid, after which it should be soaked in old aqua fortis, and then thoroughly rinsed. It should be soaked long enough to have a uniform metallic appearance, and the bath should be large enough in volume to prevent its heating up from the hot work. The best results are obtained with straw-colored aqua fortis, as the white is too weak, and the red, too strong. In diluting the sulphuric acid, it should always be poured into the water slowly, as heat is generated, and too rapid mixing generates so much heat that the containing vessel is liable to crack and the escaping liquid to cause burns. To pour water into sulphuric acid will cause an explosion that is almost sure to result in serious, if not fatal, burns from the flying liquid.

A good method of removing these films, without heat, is to soak the work in a "pickle" composed of spent aqua fortis until a black scale is formed, and then dip it for a few minutes into a solution composed of 64 parts of water; 64 parts of commercial sulphuric acid; 32 parts of aqua fortis; and 1 part of hydrochloric acid. After that the work should be thoroughly rinsed several times with distilled water. If the strong aqua fortis is used for the pickle in which the work is soaked, it will cause a too rapid corrosion of the copper during the time of the solution of the protoxide. Hence, the spent aqua fortis is more satisfactory on account of its slower action, and it also saves the cost of new.

Brass Colors. When brass contains 10 per cent of zinc, the mixture has a true bronze color. With 15 per cent of zinc, the brass has a light orange shade. When the amount of zinc reaches 20 per cent, the color of the mixture is greenish-yellow, and is known as "green brass." With 25 per cent of zinc, the color is practically that of the 20 per cent mixture so that this, too, is a "green brass." Brass with 30 per cent of zinc has the true, yellow brass color. The same is found with 35 per cent of zinc, but at about this point the yellow color begins to disappear, for with 40 per cent of zinc, a reddish-yellow color is found. Brass, therefore, that has a reddish-yellow shade will always contain more than 35 per cent of zinc. The "dead line" seems to be about 38 per cent of zinc, for, at this percentage, the transition from the real yellow to the reddish-yellow begins. When the zinc is increased to 45 per cent, the color of the brass is a rich golden shade and may be called "orange." The mixture containing 50 per cent of zinc has also a golden shade, but richer than the 45 per cent zinc alloy. With 55 per cent of zinc, the color resembles that of 14-carat gold. When 60 per cent of zinc is reached, the brass has a yellowish-white shade, and as the quantity increases, the color becomes white, and finally gray.

Brass Forging. Parts formed to the required shape in dies and made from forgeable brass rod are being used to replace many small castings and screw machine parts. The production of these die-formed pieces may be either by a forging or a hot-pressing process. The term "brass forging" is applied more particularly when dies are used in conjunction with some type of power hammer, such for example as a drop hammer or steam hammer. The heated brass rod is formed in dies by a succession of blows so that the operation is actually one of forging. Hot pressing, according to approved usage of the term, relates more specifically to the use of some form of press in conjunction with suitable dies for forming heated brass slugs by a single press stroke. Thus the metal is forced to fill the die cavity by a power-

ful squeezing or pressing action, rather than by a succession of blows. Parts produced by hot pressing have also been called die-pressed castings, but the term casting in this connection is somewhat misleading.

Advantages of Brass Forgings: Brass forgings average 50,000 pounds per square inch tensile strength, as compared with 20,000 to 30,000 pounds per square inch for brass castings. Forgings are made of virgin metal. It is impossible to make a porous forging; while with castings it is difficult to know whether they will leak or not. Forgings are never scrapped or tested for leaks. Forgings contain no sand to dull and wear out tools, and consequently, the life of tools used on forgings is many times longer than that of tools used on sand castings. Forgings are clean, and alike as to strength, shape or size. When chucked, they run true, and for this reason, less allowance for finish is required on a forging. Considerable saving can be shown on screw machine parts, where 30 per cent or more of the stock is turned into chips. If a part has a flange on it, or a hub on each side, it will be economical to forge it. Take the case of piano caster rollers made of bar stock; the bar stock costs $150 for a thousand parts; if forged, the material costs approximately $70 per thousand parts.

Composition of Forging Rod: The composition of forging rod for brass forgings varies little from a 60-40 mixture. The S.A.E. No. 88 specification of forging rod gives copper 58½ to 61½ per cent; lead 1½ to 2½ per cent; and the remainder, zinc. This material forges and machines freely.

Forging Equipment: Board drop-hammers for brass forging generally range from 400 to 2000 pounds, and the steam hammers from 300 to 1500 pounds. Gas, oil, or electric furnaces are used to heat the forging rod and slugs. Owing to the small permissible variation in the heat to get the best results, accurate temperature controls should be provided.

Brass Forging Dies: Dies for board-drop and steam hammers are made of a low-carbon steel. Their average life ranges from 50,000 to 150,000 forgings. This long life is made possible by spreading the operation over several sections of the die. Most dies have, in addition to the finished pair of die cavities, a roller to draw out the stock to a smaller section; a former to form it to the approximate shape of the die cavity; a blocker to prepare the bar to the approximate shape of the finished impression; and a cut-off to cut the forging off the end of bar.

Brass forging dies require approximately the same draft as dies for steel. It is possible, when the sections are not too high, to use a draft of 3 degrees instead of 5 and 7 degrees as is customary on the deeper sections. Due to the softness of brass

and copper, it is of the utmost importance to smooth and polish the dies very highly. If a scratch is left, the brass is driven into this crevice, and in a short time a crack will develop.

Accuracy of Brass Forgings: Forgings will vary by plus or minus 0.005 inch, on an average. If a part is 6 inches long, it will vary in length about 0.010 inch. In commercial practice, forgings may vary by plus or minus 0.0075 inch, unless otherwise specified. See Hot-pressed Brass Parts.

Brass, High. See High Brass.

Brass History in United States. Brass was produced in the American Colonies for the first time at the iron foundry of John Winthrop, Jr., in Lynn, Mass., in 1644. A brass industry, however, did not develop until over a century later. About 1750, John Allen established a brass factory in Waterbury, Conn., the brass being used chiefly in the manufacture of buttons. From this humble start the brass industry of the United States has grown to be a great industry.

Brass, Hot-Pressed. See Hot-pressed Brass Parts.

Brass, Low. See Low Brass.

Brass Pipe. Seamless brass pipe suitable for use in plumbing, boiler feed lines, etc., has the following compositions, in per cent, according to A.S.T.M. Specification B43-33:

Muntz Metal: Copper, 59 to 63; lead, 0.50 max.; iron, 0.07 max.; tin, 0.15 max.; zinc, remainder.

High Brass: Copper, 65 to 68; lead, 0.80 max.; iron, 0.07 max.; tin, 0.15 max.; zinc, remainder.

Admiralty Metal: Copper, 70 to 73; lead, 0.07 max.; iron, 0.07 max.; tin, 0.90 to 1.20; zinc, remainder. Note: The ideal composition for Admiralty Metal is 70 per cent copper, 29 per cent zinc, and 1 per cent tin. Better tubes will be obtained by adhering closely to this composition, particularly as to tin.

Red Brass: Copper, 84 to 87; lead, 0.07 max.; iron, 0.07 max.; tin, 0.15 max.; zinc, remainder.

Diameters: The actual outside diameters of brass pipes are the same as the outside diameters of steel pipes. For example, a 1-inch nominal size has an outside diameter of 1.315 in both steel and brass. See Pipe Corrosion.

Brass Rod. S.A.E. Standard Specification No. 88 applies to rods capable of being forged readily while hot and easily machined. These rods may be produced by hot-rolling or extrusion, and may be finished by cold-drawing, if necessary, to meet requirements as to size.

Composition: Copper, 58.50 to 61.50; lead, 1.50 to 2.50; iron, max., 0.15; materials other than copper, lead and zinc, max., 0.35 per cent; zinc, remainder.

Physical Properties: Hot-pressed forgings should have an ultimate strength of 45,000 and a yield point of 18,000 pounds per square inch. The elongation in 2 inches is 25 per cent.

Brass Rod, Free-Cutting. See Free-cutting Stock.

Brass Rod, Hard and Soft. The terms "hard" and "soft" as applied to brass rod have different meanings to the manufacturer and to the user. To the user, the term "hard," applied to brass rod, means that it is difficult to cut; the term "soft" means that it is easy to cut. To the manufacturer, the term "hard" means high tensile strength, stiffness, and high Brinell, scleroscope, and Rockwell hardness numbers, and does not necessarily mean that the rod is difficult to cut. The manufacturer uses the words "free-cutting" and "not free-cutting" to describe the cutting qualities.

In steel and iron, metal that has high strength and Brinell hardness is generally not free-cutting, and metal that has low strength and Brinell hardness is free-cutting. In brass, the same relation does not necessarily hold. In brass, the most important factor in determining free-cutting properties is the lead content. This should be maintained at about 3 per cent; if it runs much above this, trouble will be experienced in manufacture, and in the rod itself, due to lack of strength; if it runs below 3 per cent, the maximum free-cutting properties will not be attained. The difference in lead content explains why brass rod made abroad does not cut so readily as similar stock made in this country. It also explains why tubing as a rule is "harder" (in the meaning of the user) than brass rod. If the lead content of brass tubing is higher than about 1 per cent, difficulty is met with in manufacture. The hardness (strength, stiffness, etc.) of brass is controlled largely by the amount that it is drawn, either from the extruded size or after the last annealing. This has comparatively little to do with the free-cutting properties of the rod. The rod should be drawn stiff enough so that the cutting tools will not push it out of shape. The required results are obtained by accurate control of the composition and processing of the rod.

Brass Sheets. There are three grades designated as A, B and C. Grades A and B are used for deep drawing. As the brass is used for many purposes requiring properties not indicated by ordinary physical test data, it is often advisable to obtain from the manufacturer brass having an anneal or temper adapted to actual requirements.

Temper of Sheet Brass: The tempers are designated as Quarter Hard (1); Half Hard (2); Three-Quarter Hard (3); Hard (4); Extra Hard (6); Spring (8); Extra Spring (10). The numbers following each temper designation represent the amount of reduction in B. & S. gage numbers when the brass sheets are rolled. The greater the reduction, the harder the brass.

Composition of No. 70: Copper, (Grade A) 68.50 to 71.50, (Grade B) 66 to 69, (Grade C) 64.50 to 67.50; lead, max., (Grade A) 0.07, (Grade B) 0.07, (Grade C) 0.35; iron, max., (Grade A) 0.04, (Grade B) 0.04, (Grade C) 0.06 per cent; zinc, max., (Grades A, B and C) remainder.

Brass Tubing. Seamless brass boiler tubes for locomotive boilers, according to A.S.T.M. Specification B14-18, has the following composition, in per cent: Copper, not under 69; lead, not over 0.50; iron, not over 0.10; materials other than copper and zinc, not over 0.50; zinc, remainder. These tubes are cold drawn to size.

Brass Wire. Brass wire is generally composed of from 64 to 74 per cent of copper and the remainder is chiefly zinc. The tensile strength ranges from 40,000 to 100,000 pounds per square inch, increasing with the percentage of zinc in the alloy.

Brass Wire for Springs: S.A.E. Standard No. 80 is used for making springs. Grade A is intended for severe service, and Grade B for ordinary conditions. Composition: Copper, (Grade A) 70 to 74, (Grade B) 64 to 68; lead, max., (Grades A and B) 0.10; iron, max., (Grade A) 0.06, (Grade B) 0.07 per cent; zinc, (Grades A and B) remainder.

This wire has a tensile strength of at least 100,000 pounds per square inch, and it should be capable of being bent through an angle of 180 degrees around a wire of the same diameter without breaking.

Wire for Brazing: S.A.E. Standard No. 82 is suitable for brazing and torch welding. This wire should be soft annealed and the surface should be clean and free from scale or other foreign matter.

Composition: Copper, 59 to 62; lead, max., 0.30; iron, max., 0.06 per cent; zinc, remainder.

Brastil. A copper-base brass die-casting alloy having the color of white gold, with high strength and hardness and high resistance to corrosion, fatigue, and shock. Copper content, 81 per cent; tensile strength in die-castings, from 90,000 to 95,000 pounds per square inch; elongation, from 10 to 17 per cent in 2 inches; Brinell hardness, 160 to 180. Parts ordinarily made from steel because of the strength required can be cast from this alloy. Suitable for high-strength die-castings in general.

Brazed-Seam Process. A method for making brass tubing, in which a brass plate is bent into tubular form and welded or brazed at the joint. The brazed tube is afterwards drawn to size through dies.

Brazilian Corundum. A natural abrasive obtained from Brazil, containing about 76 per cent of crystalline alumina, which constitutes the cutting material of the abrasive. Brazilian corundum is not considered of as high a grade as *Canadian corundum.*

Brazing. Brazing is a method of joining metal parts together by means of an alloy known as *spelter solder,* or simply as *spelter,* which is melted into the joint and unites with the metals. Brazing is practically the same as *hard soldering,* but, according to the commonly accepted meaning of the two terms, there is the following distinction: Brazing means the joining of metals by a film of brass (a copper-zinc alloy); hard soldering is the term ordinarily applied when silver solder is used, the latter being an alloy of silver, copper, and zinc. For brazing, a red heat is necessary, and a flux (borax or boracic acid) is used to protect the metal from oxidation, and to dissolve the oxides formed. The part to be brazed is heated either by means of a blow-torch, gas forge, or a coke or charcoal fire. For very small work, an alcohol lamp or gas jet is often used, the heat being intensified by using a blowpipe. As a considerable amount of heat is required to melt the spelter solder, brazed work will withstand more heat without breaking or weakening than parts which are united by soldering. The chief advantage of a brazed joint, however, lies in its superior strength.

The ordinary process of brazing consists, briefly, in assembling the parts to be brazed, applying a suitable flux and the spelter solder (or hard solder) to the joint, and heating the joint until the spelter solder melts and unites with the parts to be joined. The method of holding the parts in place while brazing depends upon their shape. If practicable, they should be secured in such a way that the work can be turned over during the process of brazing without disturbing the relation of the parts, thus affording a better chance to apply the flux and spelter. Brazing is an operation requiring considerable experience. The secret of successful brazing is the thorough cleaning of the joint that is to be brazed. "Well cleaned is half brazed" is a true saying.

The principal difference between *dip brazing* and ordinary brazing is that the work is immersed into the spelter solder while the latter is in a liquid state. The spelter is contained either in a cast-iron tank or graphic crucible, the size of which depends upon the size of the parts to be brazed. *Muffle brazing* differs from ordinary brazing in that the parts to be united are enclosed

in a tube or muffle. This insures uniform heating, clean smooth surfaces, and is especially adapted to brazing alloys, the melting temperatures of which are rather close to that of the spelter.

Brazing, Hydrogen Process. By the use of atmospheres of protective gas in electric furnaces, steel parts used in the manufacture of complicated assemblies can be united by a strong alloy weld. This method, known as hydrogen brazing, involves the welding together of the parts to be joined by means of a copper flux. The theory of the process involves the reducing action of a hydrogenated atmosphere, which thoroughly cleans the surfaces to be joined, and the capillary attraction of the fluid copper, causes it to diffuse quite generally over the surface and to be drawn into the minutest joints between the parts. The protective atmosphere is also essential during the cooling period, and for this reason the usual type of furnace cannot be used.

Bright Annealing Application: Another application on which the protective gas envelope is used to advantage is bright annealing steel in sheet or fabricated form, for nickel, monel and certain other non-ferrous metals, to save the cost of annealing pots, handling, pickling, etc. Heating takes place in only one portion of the furnace, the remainder being provided with a water jacket for cooling; thus the work is both heated and cooled in the protective gas atmosphere.

Brazing, Spelter Solder. The spelters employed in brazing are composed of alloys of copper and zinc. The melting point of copper-zinc alloys may be regulated by varying the percentage of zinc, the melting temperature decreasing as the proportion of zinc increases. The fusing point of spelters should be as close as possible to that of the article to be brazed, as a more tenacious joint is thereby secured. An easily fusible spelter may be made from two parts of zinc to one part of copper, but the joint will be weaker than when a spelter more difficult to fuse is employed. A readily fusible spelter may be made with 44 per cent of copper, 50 per cent of zinc, 4 per cent of tin, and 2 per cent of lead. Alloys containing much lead, however, should be avoided, since lead does not transfuse with brass and thus decreases the strength of the joint. A hard spelter for the richer alloys of copper and zinc may be produced from 53 parts of copper and 47 parts of zinc. Brass spelter is sometimes used for copper and iron articles, as these metals have a much higher melting point than brass, thus allowing the use of a richer copper alloy. In these cases tin is often added as one of the ingredients, but it should be sparingly used as it increases the brittleness of the spelter. Ordinarily the spelter solder used for brazing is obtained from manufacturers of such supplies. In making brazing spelters, it is

important that the metals used should be commercially pure, as impurities interfere with the color, malleability, and strength.

Break Clearance. The term "break clearance" is sometimes used to indicate the clearance between a blanking punch and its die. The purpose of this clearance is to reduce both the pressure required for the blanking operation and the strain on the punch; thus, the stock subjected to shearing action between the edges of the punch and die, breaks easier, which accounts for the name "break clearance."

Brickwork, Furnace. See Furnace Brickwork.

Bridge Reamers. Taper reamers used in bridge and structural iron work are generally known as *bridge* reamers or *taper bridge* reamers; they are employed for reaming the rivet holes in structural work, and are made either with a Morse taper or straight squared shank. The fluted part is tapered for part of its length and the remaining part is straight. The taper is 1 inch per foot for the ½ inch size, and increases to 1½ inch per foot for the 1¼ inch size.

Briggs Pipe Thread. The Briggs pipe thread (now known as the American Standard) is used for threaded pipe joints and is the standard for this purpose in the United States. It derives its name from Robert Briggs.

Bright Dip for Polishing. Where there are a great many brass parts to be finished, especially in shops where repair parts are refinished, a bright dip is commonly used. A piece that is badly tarnished, and that would ordinarily require a polishing or buffing operation, can be put into good condition quickly by the use of a bright dip. The parts are first thoroughly washed in a potash cleaning solution, in the same way that they are before plating. If several small pieces are to be bright dipped, it is advisable to wire them together, while in handling large pieces, a brass hook answers the purpose. After cleaning, the piece is first dipped into cold water and then into the *acid* bath. The acid solution is made of equal parts of commercial nitric and sulphuric acids; and a cupful of common salt is added to the contents of a 20-gallon crock. The piece must not be left too long in the acid—less than a second is often long enough—and one dipping is usually sufficient; but the experienced workman may find it advisable to dip a piece more than once, depending upon the nature of the metal.

Upon being taken from the acid, the piece is again dipped in cold water, after which it is dipped in a *cyanide bath* for an interval of a second or two, the purpose being to remove all signs of tarnish from the surface of the metal. In making up the

cyanide solution, 1½ pounds of cyanide crystals are dissolved in a 20-gallon crock of water. In some cases, it may be found advisable to dip the work in the cyanide solution two or three times; no harm will be done if the work is left in it for several minutes. After being removed from the cyanide bath, the work is again dipped into cold water and then into hot water, to heat the metal so that it will dry quickly. If the drying takes too long, the work is likely to have a streaky appearance. For small work, it may be advisable to use a hot sawdust bath, which is simply a box filled with sawdust and having steam coils for heating to the required temperature.

Brinell Hardness Test. The Brinell test for determining the hardness of metallic materials consists in applying a known load to the surface of the material to be tested through a hardened steel ball of known diameter. The diameter (or depth) of the resulting permanent impression in the metal is measured. The Brinell hardness number is taken as the quotient of the applied load divided by the area of the surface of the impression, which is assumed to be spherical. Thus

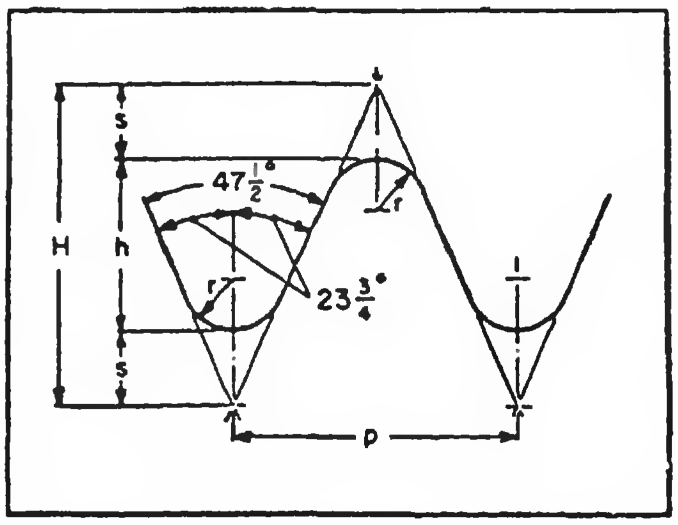
$$\text{Brinell No.} = \frac{\text{load on indenting tool in kilograms}}{\text{surface area of indentation in square millimeters.}}$$

A standard ball 10 millimeters in diameter and a load of 3000 kilograms for hard metals and 500 kilograms for soft metals is standard practice. For extremely soft metals a load of 100 kilograms is sometimes used. The load should be applied for at least 10 seconds in the case of iron and steel, and at least 30 seconds in testing other metals. A period of 2 minutes has been recommended for magnesium and magnesium alloys. For testing very small specimens or very thin specimens, it is sometimes necessary to make Brinell hardness tests with a ball less than 10 millimeters in diameter.

Briquetting Metal Chips. The *Ronay process* for briquetting metal chips, without the use of a binding material, was developed by Arpad Ronay. This process subjects every part of the material to heavy hydraulic pressure, so great that a comparatively solid briquette is formed. In order to produce the greatest possible solidity, it is necessary that the air be thoroughly expelled. The air cannot be expelled if the pressure is exerted in the mold from one direction only. It is necessary to exert direct pressure on the briquettes from at least two sides. Briquettes produced by this process, in which all air is expelled, melt in the furnace with little or no more waste than pigs of new metal. The pressure employed approximates 35,000 pounds per square inch.

Britannia Metal. Britannia metal is an alloy containing tin, antimony, and copper as the chief ingredients. It is made in various compositions, many of which also contain zinc, lead, or bismuth. Britannia metal is used extensively in the manufacture of silver-plated ware. While the color of Britannia metal is white, it is almost invariably silver-plated. Britannia metal is made in much the same manner as babbitt metals, by first melting the copper in a crucible with a small percentage of tin or antimony. This mixture is afterwards added to the balance of the tin and antimony alloy. Several compositions of Britannia metal, determined by analysis, are as follows: Tin, 90 per cent; antimony, 6 per cent; copper, 2 per cent; bismuth, 2 per cent. Tin, 86 per cent; antimony, 10 per cent; copper, 1 per cent; zinc, 3 per cent. Tin, 80 per cent; antimony, 10 per cent; copper, 3 per cent; zinc, 1 per cent; lead, 6 per cent. Tin, 70.5 per cent; antimony, 25.5 per cent; copper, 4 per cent.

British Association Thread. This form of thread is similar to the Whitworth thread in that the root and crest are rounded (see illustration). The angle, however, is only 47 degrees 30 min. and the radius of the root and crest are proportionately larger. This thread is used in Great Britain and, to some extent, in other European countries for very small screws. Its use in the United States is practically confined to the manufacture of tools for export. This thread system was originated in Switzerland as a standard for watch and clock screws, and it is sometimes referred to as the "Swiss small screw thread standard."



British Association Thread

British Standard Fine Screw Thread (B.S.F.). The form of this thread is the same as that of the Whitworth thread, but the number of threads per inch for a given diameter is greater than in the Whitworth standard system.

British Thermal Unit. The unit quantity of heat adopted in the English-speaking countries is the British thermal unit (B.T.U.). A British thermal unit is the quantity of heat that is required to raise the temperature of one pound of pure water one degree F. Strictly speaking, the measure or unit of heat is the quantity required to raise the temperature of one pound of water one degree, at its point of greatest density. Although this occurs at about 39 degrees F., it is customary, in ordinary com-

putations, to disregard the temperature and to define a heat unit or British thermal unit simply as the quantity of heat required to raise the temperature of one pound of water one degree. The number of foot-pounds of mechanical energy equivalent to one British thermal unit is called the *mechanical equivalent of heat* and equals 778 foot-pounds. One foot-pound = 0.001285 heat unit. The various power equivalents of a British thermal unit are as follows: 1 B.T.U. = 1052 watt-seconds = 778 foot-pounds = 0.252 kilogram calorie (French or metric thermal unit) = 0.000292 kilowatt-hour = 0.000391 horsepower-hour = 0.00104 pound of water evaporated at 212 degrees F.

British Thermal Unit Values. See Heat Density; Heat Equivalent of Work; Fuel Oil Heating Value; Gasoline.

British Wire Gages. The standard British wire gage, usually known simply as Standard wire gage (frequently abbreviated S.W.G.), but also known as the New British Standard (abbreviated N.B.S.), and also frequently known as the British Legal Standard or Imperial wire gage, is the legal standard for wires in Great Britain, by order in Council, August 23, 1883. The Birmingham or Stub's iron wire gage is also used for some purposes, especially for designating the sizes of brass wire, but only to a limited extent. On the whole, it may be considered obsolete; while it is sometimes referred to as Stub's gage or Stub's iron wire gage, it should not be confused with the Stub's steel wire gage, which is still a commonly used gage for steel wire, drill rod, and drill diameters. The Birmingham wire gage is usually abbreviated B.W.G.

Brittleness. Brittleness is a qualitative term indicating lack of toughness. Brittle metals cannot be deformed appreciably without shattering and have little shock resistance.

Broaching Process. Broaching consists in cutting away metal to obtain a given form, size and finish by using a broach (or several successive broaches in some cases) having a series of teeth which progressively increase in size or height from the starting end, so that each tooth takes a light cut and thus, by a succession of cuts, forms a surface quickly and accurately. In other words, the shape of the machined surface is a reproduction of the shape of the final cutting edges on the broach. Broaching is applied to many different classes of work. A simple example of internal broaching consists in forming a hole of square, hexagon, or other form from a drilled hole. Originally, broaching was restricted to internal work of this kind and to the cutting of keyways; but now many flat or other external surfaces are machined by this process.

Some machine parts are finished by broaching because it is the only practical method. In other cases, broaching is selected in preference to other methods because for certain classes of work, especially in interchangeable manufacture, it is more rapid, and, consequently, less expensive. Broaching, when properly applied, is also very accurate and leaves a finish of good quality. Generally speaking, broaches are expensive tools, but they often make it possible to machine either internal or external surfaces in a few seconds. This explains the extensive use of the broaching process in automotive and other plants where duplicate parts must be produced in large quantities and frequently to given dimensions within small tolerances.

Broaching Machines: The general function of a broaching machine is to supply the power required for broaching and provide whatever stroke and speed adjustments may be needed. The machine must also be equipped with a suitable work-holding fixture and with means of supplying a cutting fluid to the broach. Modern broaching machines, as a general rule, are operated hydraulically rather than by mechanical means. Hydraulic operation is efficient, flexible in the matter of speed adjustments, low in maintenance cost and the "smooth" action required for fine, precision finishing may be obtained. The hydraulic pressures required, which frequently are 800 to 1000 pounds per square inch, are obtained from a motor-driven pump forming part of the machine and connected with the cylinder containing the broach-operating piston or plunger. Broaching machines for general use are so designed that the length of the stroke can be adjusted to suit the length of the broach. The broach length depends upon the number of teeth needed to remove a given amount of metal. The cutting speeds of broaching machines may be varied for different materials and operations. These speeds frequently are between 20 and 30 feet per minute, and the return speeds often are double the cutting speed or higher, to reduce the idle period.

Bromine. Bromine is one of the non-metallic chemical elements allied in its chemical relations to chlorine and iodine. Its chemical symbol is Br, and its atomic weight, 79.9. At ordinary temperatures it is a dark reddish liquid which is opaque except when in thin layers. It has a specific gravity of 3.2 at 32 degrees F. It changes from the solid to the liquid state at —7 degrees C. (+19 degrees F.); its boiling point is at 59 degrees C. (138 degrees F.); its latent heat of fusion equals 16.18 calories; latent heat of vaporization, 45.6 calories; and specific heat, 0.107. Bromine is slightly soluble in water. When dropped on the skin, it produces corrosive sores. The chief uses of bromine are in

analytical chemistry, where it is of some importance on account of its oxidizing action. The salts of bromine are widely used in photography, especially bromide of silver. Bromine does not occur free in nature, but is manufactured mainly from magnesium-bromide.

Bronze. Bronze is an alloy composed mainly of copper and tin in variable proportions, and sometimes containing small percentages of zinc, antimony, lead, aluminum, phosphorus, or manganese. There are many compositions known as bronze.

S.A.E. Standard No. 62: This is a strong general utility bronze suitable for severe working conditions and heavy pressures. Typical applications include gears; bearings; bushings for severe service; valve guides; valve-tappet guides; camshaft bearings; fuel pump, timer and distributor parts; connecting-rod bushings; piston-pins; rocker lever; steering sector and hinge bushings; starting-motor parts.

Composition of No. 62: Copper, 86 to 89; tin, 9 to 11; lead, max., 0.20; iron, max., 0.06; zinc, 1 to 3 per cent.

Physical Properties: Tensile strength, 30,000 pounds per square inch; yield point, 15,000 pounds per square inch; elongation in 2 inches (or proportionate gage length), 14 per cent.

S.A.E. Standard No. 63: This general-utility bronze combines strength with fair machining qualities. It is especially good for bushings subjected to heavy loads and severe working conditions. It is also used for fittings subjected to moderately high water or oil pressures.

Composition of No. 63: Copper, 86 to 89; tin, 9 to 11; phosphorus, max., 0.25; zinc and other impurities, max., 0.50; lead, 1 to 2.50 per cent.

Physical Properties: Tensile strength, 30,000 pounds per square inch; yield point, 12,000 pounds per square inch; elongation in 2 inches (or proportionate gage length), 10 per cent.

S.A.E. Standard No. 660: This composition is widely used for bronze bearings. Typical applications in the automotive industry include such parts as spring bushings, torque tube bushings, steering-knuckle bushings, piston-pin bushings, thrust washers,

Composition of No. 660: Copper, 81 to 85; tin, 6.50 to 7.50; lead, 6 to 8; zinc, 2 to 4; iron, max., 0.20; antimony, max., 0.20; other impurities, max., 0.50 per cent.

Physical Properties: Tensile strength, 30,000 pounds per square inch; yield point, 14,000 pounds per square inch; elongation in 2 inches (or proportionate gage length), 18 per cent.

S.A.E. Standard No. 67: This is a soft bronze with good anti-friction qualities. Water-pump bearings represent one application.

Composition of No. 67: Copper, 76.50 to 79.50; tin, 5 to 7; lead, 14.50 to 17.50; zinc, max., 4; iron, max., 0.40; antimony, max., 0.40; other impurities, max., 1 per cent.

Physical Properties: Tensile strength 20,000 pounds per square inch; elongation in 2 inches (or proportionate gage length), 10 per cent.

A number of other bronzes are made with varying compositions. *Bell metal* is a bronze containing 80 per cent of copper and 20 per cent of tin, and the metal used for Chinese gongs is a bronze of similar composition. The name "bronze" is also used for alloys with copper and various other metals, even when these alloys are nearly or entirely lacking in tin; thus, for example, aluminum bronze is mainly an alloy of copper and aluminum. See also Manganese-bronze; Non-gran Bronze; Phosphor-bronze; Silicon Bronze; Tobin Bronze; Aluminum Bronze.

Bronze, Early Use. Copper was first produced from ores about 5000 years before the Christian era. About this time bronze became known, not by melting copper and tin together, but rather because the ores available contained tin, nickel and small amounts of other metals, and produced alloys harder and stronger than copper. The Bible mentions Tubal Cain as a worker in brass and refers to the alloy in several places. There is reason to believe that not brass but bronze is intended. In the first century Dioscorides makes the earliest unmistakable reference to brass (an alloy of copper and zinc); nevertheless, it was known to the Far East long before. Owing to confusion in names, no approximation of a definite time when brass came into use is possible.

Bronze Gear Castings. See Gear Castings, Bronze.

Bronzing. Bronzing is a process by means of which a bronze-colored surface is produced on objects made from other metals or from wood, plaster, or other materials. A bronze-like color can be produced by exposing iron or steel parts to the vapors of heated *aqua regia,* then dipping them in melted vaseline, and finally heating them until the vaseline begins to decompose, when they are wiped off with a soft cloth. Bronze-like colors may also be produced by slightly heating the work, covering the surface with a paste of antimony chloride, also known as "bronzing salt," and letting the object stand until the desired color is obtained. The paste of bronzing salt may be made more active by adding a small quantity of nitric acid. Bronze colors can also generally be produced on metals by the action of dilute nitric acid and sal-ammoniac. The so-called "antique bronze" appearance is produced by painting over the bright metal with a solution of sal-ammoniac, cream of tartar, silver nitrate, and common salt. Plaster and wood are bronzed by first coating the articles with a

sizing and then covering them with a bronze powder produced by powdering brass or bronze.

Brown & Sharpe Taper. A standard taper used for taper shanks on tools such as end mills and reamers, the taper being approximately ½ inch per foot for all sizes except for taper No. 10, where the taper is 0.5161 inch per foot. Brown & Sharpe taper sockets are used for many arbors, collets, and machine tool spindles, especially milling machines and grinding machines. In many cases there are a number of different lengths of sockets corresponding to the same number of taper; all these tapers, however, are of the same diameter at the small end.

Brown & Sharpe Wire Gage. The Brown & Sharpe wire gage, also known as the American wire gage, is the gage universally recognized in the United States as the standard gage for copper wires and wires of metals other than steel. The diameters of the wires of successive numbers increase according to a geometrical ratio. The diameter of each succeeding number can be found by multiplying the diameter of the preceding number by 1.123, this being the ratio of the geometrical progression. The basic size is No. 36 wire, which is 0.005 inch in diameter

Brushes, Motor. The brushes of a direct-current machine are those parts of the mechanism which, being held in some form of flexible holder, rest upon the commutator surface at proper points about its periphery and distribute current to or from the commutator segments. The brushes also perform the function of uniting the commutator segments to which are connected adjacent coils to be commutated, thus making a proper continuous circuit around the armature. They are made of a conducting material, generally of graphite or carbon, although metal or metal compound brushes are used extensively in some special applications. The brush material, being relatively soft, forms a good surface of contact with the commutator, thus reducing the resistance to the passage of current between the commutator and the external source of power to a minimum. The brush rigging or holders and mountings must be such as to afford minimum inertia to the brush, since its function is to aid the brush in following the more or less uneven surface of the commutator when the latter revolves.

Brush-Shifting Motor. A brush-shifting motor is an electric motor consisting of a stator with a three-phase distributed winding or a single phase winding and a rotor similar to that of a regular direct-current motor, but with a larger number of brushes which can be shifted through worm-gearing by means of a handwheel. This type of motor is used in order to obtain speed control, as it may be started, accelerated, stopped, and reversed by shifting the brushes.

Btu. See British Thermal Unit.

Bucket Conveyors. Bucket conveyors consist of a series of equally spaced buckets attached either to a belt or a chain. Grain conveyors are always encased in wooden and steel casings, and the casings are nearly always vertical. The usual support for the buckets in this case is belting—either leather, cotton, or rubber. For coal, coke, and other heavy materials, the buckets are fastened to chain links, either single or double strand, depending upon the capacity for which the conveyor is designed; and, in this case, the conveyor casing is usually carried in a slanting position. Conveyors in a vertical position are only suitable for specifically light material and can be run at a circumferential velocity of from 250 to 350 feet per minute. Conveyors for heavy material must be wholly or partially inclined to give a clean delivery without scattering, and they should run at a speed of from 50 to 160 feet per minute. Bucket conveyors should always be driven from the top so that the upward side of the conveyor (the side containing the load) can be tight, while the empty side will run slack.

Bucket Elevator. A device practically the same as a *bucket conveyor*, except that it is used in a vertical or nearly vertical direction. It consists chiefly of a belt or detachable link chain to which buckets containing the material to be lifted are attached, the belt or chain passing over pulleys or sprockets at the top and bottom. The top pulley or sprocket is power-driven.

Bucking. An electrical term used to designate the condition where the potential from one source is opposing that from another source.

Buffing. Buffing is the process of obtaining a very fine surface, having a "grainless" finish, on metal objects, by means of soft wheels of felt to which a fine polishing material is applied, or by wheels formed of layers of cotton cloth. The term "buffing" is often used interchangeably with "polishing." The operation is performed with any wheel to the face of which the abrasive is loosely applied, rather than glued as in polishing. Buffing is not so harsh an operation as polishing. The abrasives which are glued to a polishing wheel are intended to grind away roughness that the grinding wheel or other cutting tool leaves—unevennesses that are often discernible only with the aid of a microscope. Buffing, on the other hand, employs such soft cutting materials as tripoli, lime, crocus or rouge prepared in cake form with tallow and other greases as a body, this being applied to the cloth buff by hand from time to time so that the face of the buff is given a coating of this composition. Some metals, like

German silver and white metal, are buffed before plating. Pocket-knife blades are polished with emery and then highly finished (colored) by what is known as "crocus polishing," in which a wheel, similar to a leather-faced wood polishing wheel is used for buffing. Steel parts to be plated are usually prepared for plating by polishing, buffing being employed to give a luster to the plated surface. The term *sand buffing* relates to the finishing of German silver, white metal, and similar materials. As compared with the ordinary buffing operation that is used only to produce a very high finish, sand buffing actually removes considerable metal as in rough polishing or flexible grinding. For sand buffing, rotten-stone and pumice are loosely applied.

Buffing Machines. See Polishing or Buffing Machines.

Buffing Wheels. Buffing wheels are manufactured from disks (either whole or pieced) of bleached or unbleached cotton or woolen cloth, and used as the agent for carrying abrasive powders, such as tripoli, crocus, rouge, lime, etc., which are mixed with waxes or greases as a bond. There are two main classes of buffs known as the "pieced-sewed" buffs, which are made from various weaves and weights of cloths, and the "full disk" buffs which are made from the best sheeting and shirting. Bleached cloth is harder and stiffer than unbleached cloth, and is used for the faster cutting buffs. Coarsely woven unbleached cloth is recommended for highly colored work on soft metals, while the finer woven unbleached cloths are better adapted for the harder metals. A stiff buff when working at the usual speed is not suitable for "cutting down" soft metal or for use on light plated ware, but is used on the harder metals and for heavy nickel-plated articles.

Buffing Wheel Sizes. Full disk buffing wheels recommended by the polishing industry for general adoption are all 20 ply and have the following outside diameters: 4, 5, 6, 7, 8, 11, 13, 14, 17, 18 and 20 inches. This "simplified practice" recommendation of the Bureau of Standards has been accepted by the Grinding Wheel Manufacturers' Association of United States and Canada, the Metal Finishing Equipment and Materials Institute, the Metal Polishers' International Union, and by various other associations, as well as by numerous manufacturers.

Buffington Process. A method for producing a protective oxide coating on iron and steel. The articles to be coated are immersed cold in a molten bath of manganese dioxide and potassium nitrate; the articles are next removed and hung over the iron pot in which the bath is contained, so as to be exposed to

the fumes from the mixture. They are then placed in boiling water. Colors varying from blue to bronze may be produced in this manner.

Built-Up Section. A structural beam, column, or strut, composed of two or more single structural shapes.

Bulging Method of Forming Shells. In the manufacture of many sheet-metal parts, operations, such as bending, forming, and expanding can be performed economically by the hydraulic bulging method. The work is placed in a die, which is usually split, and water under a pressure varying from 600 to 1200 pounds per square inch is admitted from either a hydraulic accumulator or a force pump. A force pump is generally sufficient for the purpose, and gives a ready means of varying the fluid pressure; the initial cost is also low. In the case of hollow work, the water under pressure is admitted directly into the work itself, so that in this respect it differs from the older method of hydraulic bulging, in which the quantity of water is measured, put into the receptacle to be bulged, and the operation performed under a power press.

With the improved method, a power press is not required, and the construction of the dies is so simple that their first cost is much less than when the combined mechanical and hydraulic operation is employed. Furthermore, the method of operation does not depend for its success upon the watchfulness of the operator in measuring the fluid. It is merely necessary to insert the work in the lower half of the dies, clamp the top half in position, admit the water under pressure from a suitable water cock and drain the water off after the piece has been formed. Another advantage of the process is the rapidity with which the water pressure forms the article to the desired shape, the time required being not more than one-sixth that taken by the other method. An important point to be considered is the water pressure, which must be governed by the thickness of the metal and its physical characteristics. A safe pressure to use at first is about 700 pounds per square inch for annealed brass 0.020 inch thick, increasing this to approximately 1200 pounds per square inch for a thickness of 0.060 inch.

Bull Block. In wire drawing, a bull block is a machine in which wire or rod is drawn in order to reduce it into wire of the required diameter.

Bull Center Reamer. A conical reamer used for reaming the ends of large holes—usually cored—so that they will fit on

a lathe center. The cutting part of the reamer is generally in the shape of a frustum of a cone. It is also known as a pipe center reamer.

Bulldozer. The bulldozer is a machine especially adapted for bending operations, and is closely allied to the forging machine, in fact, many operations can only be done successfully on forging machines when the bulldozer is used for performing a preliminary operation. This type of machine contains a cross-head which carries one member of the forming dies; the other member of the dies is held against a die seat which is formed integral with the main base of the machine. This base or bed is horizontal and the cross-head slides upon horizontal ways or ways which are slightly inclined. The stock to be formed is placed between the dies, and, as the cross-head moves forward, the stock, which may or may not be heated, is bent to conform to the shape of the dies, the work as a rule being completed in one movement of the cross-head. While the machine is quite simple in construction and operation, many interesting types of forming tools and dies are employed on different classes of bulldozer work. Many of the tools or dies are made of cast-iron, in order to reduce the cost, and those parts of the dies which are subjected to wear are faced with hardened steel plates which may readily be replaced, if necessary. Whenever hot punching or cutting is done, high-speed self-hardening steel should be used for the working members of the tool.

Bull Wheel. The gear in a planer drive which meshes with the rack beneath the platen and through which the motion of the platen is obtained.

Bunsen Burner. The device known as the "Bunsen burner" was invented in 1855 by Prof. R. W. von Bunsen of Heidelberg, and provides a simple means for burning ordinary coal gas with an extremely hot smokeless flame. The object of the burner is to procure a flame capable of producing great heat, but which will not smoke any vessel or article heated by it. The force of gas, escaping through a small aperture, draws the air through holes in a sleeve surround the jet. The air and gas mix together, consuming the carbon produced by the decomposing gases before it becomes incandescent, and producing the flame desired.

Bunsen Cell. The Bunsen cell is one of the well-known primary electrical batteries which is, in general, similar in construction to the Daniell cell in that a zinc plate is placed in dilute sulphuric acid, but in the Bunsen battery the copper cylinder is replaced by one of carbon, and the copper sulphate solu-

tion, by strong nitric acid. The Bunsen cell gives a high electromotive force, varying from 1.9 to 1.95 volts. It has also low internal resistances, and can, therefore, be used for producing fairly large currents. The battery give off fumes of nitric peroxide and must, therefore, be placed in the open air or under an exhaust flue. The battery must be taken apart when not in use, because the mixing of the liquids through the walls of the porous jar containing the dilute sulphuric acid would render it useless after a short time. The porous jar should be placed in water after having been used, so that the zinc sulphate solution may be dissolved out of the pores of the jar. Otherwise, when the jar dries, the zinc sulphate solution will crystallize in the pores and cause the jar to crumble to pieces.

Buoyancy. Any body that is immersed in water, or in any other liquid, is subjected to an upward force equal to the weight of the mass of the liquid that is displaced by the body. This is true whether the body sinks or floats. The weight of a floating body is equal to the weight of the volume of the liquid that it displaces. The upward pressure on the body is known as *buoyancy.* It may be assumed to be exerted at the center of gravity of the displaced liquid, which point is known as the *center of buoyancy.* In a floating body, at rest on the water, the line joining the center of gravity of the body and the center of buoyancy is always vertical, and is known as the *axis of equilibrium.* If an external force causes this axis of equilibrium to occupy an inclined position, then, if a vertical line be drawn upward from the new center of buoyancy to this axis, the point where it intersects the axis is called the *metacenter.* If the metacenter is above the center of gravity, the body is in stable equilibrium, and tends to return to the original position when the external force is removed.

Weight of Submerged Body: A body submerged in water or other fluid will lose in weight an amount equal to the weight of the fluid displaced by the body. This is known as the *principle of Archimedes.* To illustrate, suppose the upper surface of a 10-inch cube is 20 inches below the surface of the water. The total downward pressure on the upper side of this cube will equal the area of the side multiplied by the product of the depth, in inches, to which the surface is submerged and the weight of 1 cubic inch of water. Thus, the downward pressure equals $10 \times 10 \times 20 \times 0.03617$ (weight of 1 cubic inch of water) $= 72.34$ pounds. The upward pressure on the under side equals $10 \times 10 \times 30 \times 0.03617 = 108.51$ pounds. The weight of the water displaced by the body equals $10 \times 10 \times 10 \times 0.03617 = 36.17$ pounds; and $108.51 - 72.34 = 36.17$ pounds.

This excess of upward pressure explains why it is comparatively easy to lift a submerged stone or other body.

Bur. See Rotary Files and Burs.

Bureau of Standards. One of the important functions of the U. S. Bureau of Standards is to compare with its own standard of measurements, the measuring instruments used by states, cities, scientific laboratories, educational institutions, and commercial corporations. The Bureau also gives advice concerning these standards and their use, and many questions of disagreement either between corporations, or between the public and a corporation, involving the use of standards, are referred to the Bureau for advice or adjustment. The Bureau also certifies the accuracy of standards of measurement, such as gages, and in addition publishes a great deal of information relating to measurements and standards of all kinds, in the form of small booklets, each dealing with one definite subject. Numerous tests and investigations are carried on in this connection. The materials of construction are also dealt with by the Bureau. The activities of the Bureau of Standards are fundamentally concerned, either directly or indirectly, with the improvement of methods of production or the quality of the output of the industries.

"Burning On" or "Casting On." The expressions "burning on" or "casting on" relate to a method of repairing or of filling in a broken part of the casting. Thus if a part has been broken from a casting it may be reunited or a new part formed, by pouring molten metal over the surface that is to be repaired until it becomes plastic or begins to melt. Two pieces that have broken apart can be united by chipping away the edges to expose the surfaces that are to be burned. They are then placed together and a core fitted around them leaving the entire top side exposed. An overflow channel is made in the core to carry the surplus metal away. The burning is accomplished by pouring a constant stream of metal onto the break until the surfaces become plastic, when the pouring is stopped, leaving the opening between the break filled with metal. There is usually quite a lot of metal to chip away after burning, but many castings have been saved by this operation, especially prior to the introduction of modern welding processes.

Burnishing. The burnishing of metals is a method of securing smooth finished surfaces by compressing the outer layer of the metal, either by the application of highly polished tools, or by the use of steel balls which, by rolling contact, produce smooth surfaces.

Burnishing of Spun or Drawn Shapes: After sheet metal is spun, or drawn in presses, the smooth, even surface which it has when it comes from the mills is changed to a rough, uneven surface having high and low spots which are hardly noticeable to the naked eye, but very easily distinguished under the magnifying glass. The working operations distend or elongate the molecules, and the annealing operation restores them to their original shape. Some shells are annealed several times before the burnishing operation is reached, besides being pickled after each annealing to remove the scale; this leaves the surface of the metal in a matted condition, as well as soft and without temper.

A spun shell can be gone over with a planisher, and hardened, but the scale and dirt is crowded into the grain of the metal and the only way to obtain a smooth surface is to buff or cut it down until this pitted face is removed, thus wasting about 10 per cent of the metal. The spinner can do this in another way, that is by skimming or shaving the uneven surface, but even more metal is wasted than by buffing, and the shell is also weakened by gouging the high places. This same shell could be left without polish, and the chuck transferred to the burnishing lathe, which runs at much greater speed than one used for spinning. After the shell is dipped right to remove all spinning dirt and scale, it can then be polished to an even surface, the uneven face of the metal being amalgamated or smoothed down to a bright surface of the proper temper; it is then colored with a cloth buff to obtain a perfect finish. The gage or thickness remains the same, as there is no dirt or scale to buff out. It is necessary to have a metal chuck in burnishing, and where the shell has been spun on such a chuck, the latter can be used for both operations. Some work can be lacquered without coloring on the buff wheel, the only operation after burnishing being to wash in hot water and dry at once in hot sawdust.

Burnishing Tools: Burnishing tools are made extremely hard and no temper is drawn. These tools have to be re-polished when they become coated with metal, the interval between polishings depending upon the texture of the metal worked and its temper, a shell that has been annealed several times coating the tool more than one that has not. The end of a burnisher may be polished quickly. A board of soft wood is used, or a strip of leather fastened to a board and to the bench, in a position convenient to the operator. Grooves are worn into the leather or board, and flour of emery and oil, or flint flour and water, is used to clean the tools, a few passes of a tool being all that is necessary to polish it.

Cleaning Work for Burnishing: The bright dip which is used to clean work before burnishing is composed of oil of vitriol (sulphuric acid), 2 parts; aqua fortis (nitric acid), 1 part. This solution should be kept in a crock set in a tank of running water, and mixed 7 or 8 hours before using, as the acids when combined heat up. It is best to mix the acids the day before using. In dipping brass, copper, and German silver, the parts are strung on a stiff brass or copper wire whenever possible. If there are no holes in the metal that can be used for stringing, they can be put in a metal or crock basket, but they cannot be handled to good advantage as it is very difficult to thoroughly wash and dip them. The work should be washed in boiling potash, and then dipped in cold water to clean the potash off and cool the metal. After cooling in the water, the parts are dipped for a few seconds in the acids, and are kept constantly in motion, so that the surfaces will be all exposed equally; they are then shaken thoroughly above the acid and immediately washed in two separate cold-water baths, then in hot soapy water, and finally in hot water, after which they are dried at once in hot sawdust. This operation will leave a bright, clean surface free from acid.

Lubricants for Burnishing: Common yellow soap, dissolved to thick paste, may be used as a lubricant when burnishing brass. The shells and the finger pads are dipped in clear water, and the tool is dipped in the soap paste before burnishing each shell. A lubricant for copper is made by dissolving about one ounce of ivory or castile soap in a gallon of water. The shells and pads are dipped in this solution, no lubricant being used on the tool. Yellow soap should not be used on copper, as the action of the resin on copper is different from that on brass, the metal being so glazed or greased that the tool works badly. For copper plate on steel, such as copperized steel oilers, etc., about one-half ounce of oil of vitriol to four gallons of water should be used. The burnishing tool should be dipped in a mixture of mutton tallow that has been melted with 5 per cent of beeswax. and the work and the finger pads should be dipped in the acid mixture. The tool is lubricated in the tallow mixture before burnishing each shell.

For German silver, the shell should be dipped in clear water, the finger pads in sour beer, and the tool in yellow soap paste. For white metal or britannia, use ivory or castile soap in the paste form for the tool, and sour beer or ox gall in water (4 ounces to the gallon) for the finger pads. Wash the work in hot alkali water (a spoonful of cream of tartar, saleratus or soda to a pail of water), and dry in hot sawdust. For burnish-

ing work which is to be lacquered, without coloring on the cloth buff, use thin glue for a lubricant, and also on the finger pads. When the part is burnished, put it in saleratus water to keep it from tarnishing; then wash in hot water and dry in hot sawdust.

Burnishing Broach. This is a broach having teeth or projections which are rounded on the top instead of being provided with a cutting edge, as in the ordinary type of broach. The teeth are highly polished, the tool being used for broaching bearings and for operations on other classes of work where the metal is relatively soft. The tool compresses the metal, thus making the surface hard and smooth. The amount of metal that can be displaced by a smooth-toothed burnishing broach is about the same as that removed by reaming. Such broaches are primarily intended for use on babbitt, white metal, and brass, but may also be satisfactorily used for producing a glazed surface on cast iron. This type of broach is also used when it is only required to accurately size a hole.

Burnishing by Ball Process. Barrel burnishing is done to finish, polish, or brighten metal parts without cutting away the stock, steel balls acting as individual burnishing tools. Tilting barrels are sometimes used for ball burnishing when the work is small, but the horizontal type is universally recommended. The hardened and polished steel balls roll over the work while under pressure, and rub against the parts evenly. The pressure is caused by the weight of the balls and the work in the barrel. Some manufacturers claim that a horizontal barrel, large in diameter and comparatively small in width, is the best type to use, because a certain quantity of balls will not spread over so large a space, and will therefore create a greater pressure on the work. In this type of barrel, about two pecks of steel balls should be used for one peck of work, and to this should be added a sufficient quantity of soapy water to rise one inch above the contents of the barrel. Soapy water serves as a lubricant. About six ounces of pure soap or soap chips without much alkali should be put in each pail of water. Another manufacturer claims that a barrel of small diameter, and comparatively long, completely filled with work, balls, and soapy water, is more efficient than the type just mentioned. It is said that the work then passes constantly and evenly through the mass of balls without bumping and falling against each other.

Polygon-shaped barrels prevent the work from bunching together and sliding instead of tumbling inside the barrel. Balls from 1/16 to ¼ inch in diameter are generally used, the size depending on the work and dimension of the cavity or corners

in the pieces; the balls should be small enough to enter all cavities, and to insure this, a round steel slug with a fin-like edge is sometimes used. Articles to be barrel-burnished must be cleaned and must be free from oil or dirt. Double and triple burnishing barrels permit of burnishing more than one class of work at a time. Burnishing barrels permit the finishing of hundreds and thousands of small pieces at one time quickly and inexpensively.

Burnishing Dies. When an exceptionally good finish or polish is required, blanks which have been trimmed in a shaving die are pushed through what is known as a *burnishing* die. Such a die has an opening which tapers slightly inward toward the bottom, and it is finished very smooth, so that, when the blank is forced through by the punch, the metal around the edges is compressed and polished. Naturally, the degree of finish on the blanks will depend largely upon the finish of the burnishing surface of the die.

Burnishing Lathes. A burnishing lathe is smaller than a spinning lathe, and it has only one speed although the speeds of different lathes are varied to suit the work. The countershaft is fastened to the floor under the lathe; this is necessary on account of the great speed; besides a downward pull of the driving belt causes less vibration than the upward pull of a belt from an overhead countershaft. The burnishing is done by pushing the tool over the work, beginning at the front end and pushing always against the chuck or form over which the work is held. The toolpost is used as a fulcrum and the tool, which is pressed against the work, as a lever. The tool is given a slight rotary motion, and only the thin edge or end is used. While the pressure against the work is not great, the area in contact with the metal is so small, and the speed of the lathe so high, being from 3200 to 5000 revolutions per minute, that the tool leaves a bright surface. The skill of the operator lies in passing the tool over the metal so as to leave a continuous bright surface without any trace of the tool marks; to do this the tool must be fed with regularity and without overlapping or leaving any dull places.

Burnishing Roller. The roller type of burnishing tool is sometimes used in machine shops, especially railway repair shops, for rolling the cylindrical surface of a journal, crankpin bearing surface, etc., in order to obtain a smooth dense finish. The burnishing tool consists of a hardened roller or disk which is supported by a shank held in the lathe toolpost. The leading edge or side of this disk is rounded and the burnishing is done by feeding the roller over the surface the same as in turning. The

roller may be mounted on a plain bearing, but tools of improved design are equipped with roller bearings.

Burring Machines. Special machines and tools are sometimes used to remove the burr left on machine parts by cutting tools. One design of machine is intended especially for slightly countersinking the rear ends of holes in parts produced in automatic screw machines to remove the burr left by the cutting-off tool. This machine is semi-automatic. The parts are fed by hand into a chute and are pressed against a gage-block by a reciprocating link attached to toggle levers which exert sufficient pressure to prevent the part from rotating during the burring operation. When the link withdraws to transfer another part from the bottom of the chute, the burred blank drops out of the fixture. The burring is performed by a tool held in the spindle of an automatic sensitive drill head.

Gear Burring Machine: A machine of this type is designed for removing the burrs left on the ends of gear teeth after the hobbing or cutting operation. One type of machine is provided with a burnishing tool and a shearing tool. The burnisher resembles a hob without gashes, and it meshes with the gear, thus forcing the burrs to project from the ends of the teeth at an angle so that the stationary shearing tool can readily cut them off.

Bus-Bars. The common connections to which several generators deliver their current, and from which several feeders draw their supply, are termed *bus-bars* or *busses*. These busses may be solid copper wire, tubing, or flat bars, depending upon the amount of current to be carried. Flat bars are usually 2, 3, 5, or 10 inches wide, and ⅛ or ¼ inch thick. These are, whenever possible, mounted on edge, with spaces between the laminations equal to the thickness of the bars, to allow free circulation of air to assist in cooling the bars. For small capacities, round solid wire is used, and for high voltages and long spaces, tubing is often used. Investigations have shown that the cross-section necessary to carry a given current varies with the nature of the current; for instance, bus-bars heat more when carrying 60-cycle alternating current than with lower frequency or direct current.

Bushel. See Dry Measure.

Bushing. A lining or sleeve that is inserted in a hole usually to provide convenient means of restoring a worn hole to its original size by inserting a new bushing. A "bushing" is also a pipe fitting which is used for the purpose of connecting a pipe with a fitting of larger size; it is a hollow plug with internal and external threads to suit the different diameters.

Bushing Bronze. See under Gear Castings, Bronze.

Bushing Chain. What is known as the built-up block or bushing chain resembles somewhat a roller chain, but differs from the latter in that the bushings between the side links are not provided with rollers. The operation of this rollerless chain is similar to that of the solid block chain. It will fit sprockets intended for roller chains, provided the pitch and diameter of the rollers are of corresponding size. These chains are recommended when considerable power is to be transmitted and the speed is low. The rivet wearing surface is large in proportion to the pitch of the chain.

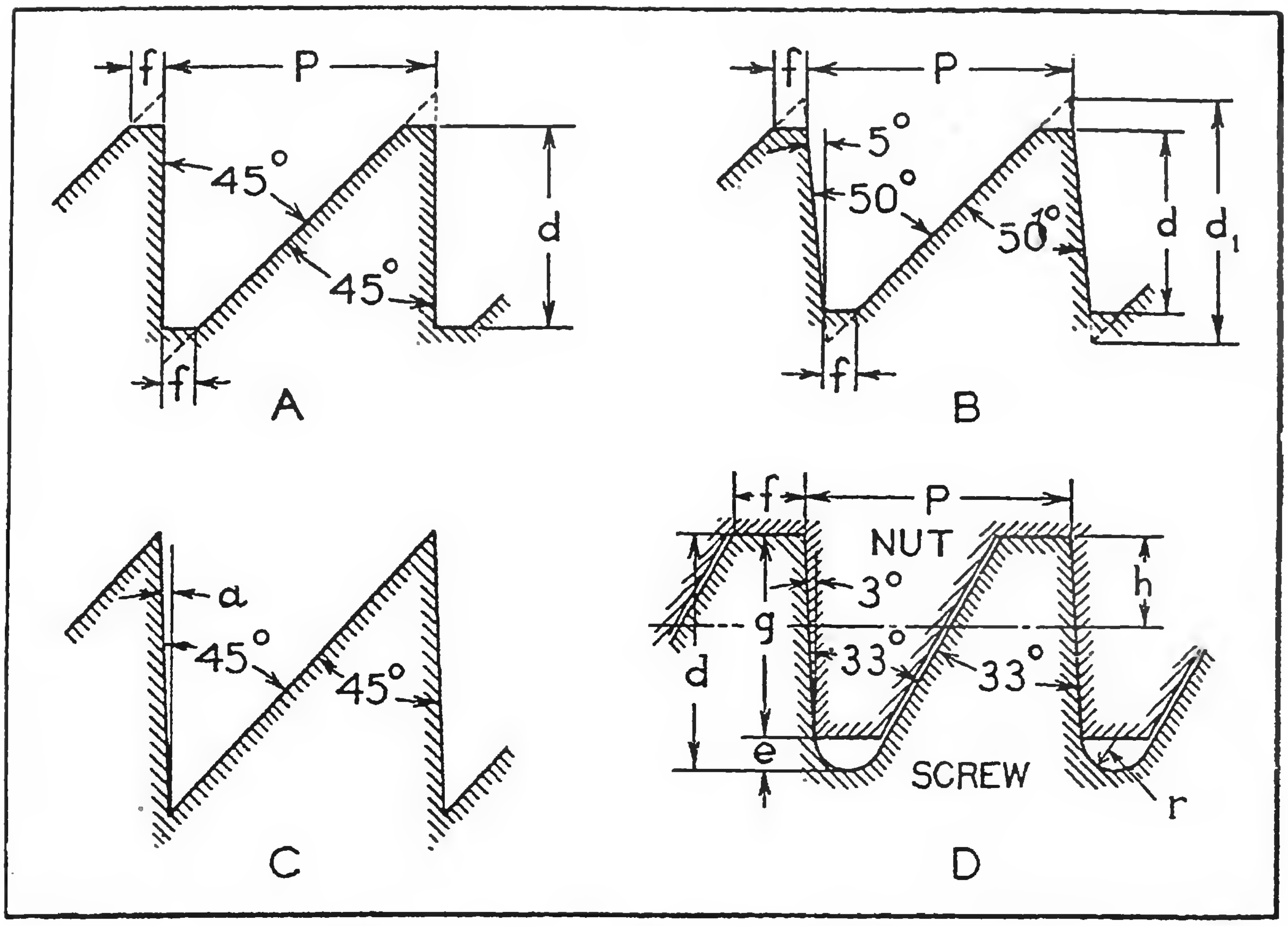
Bushings, Grinding Wheel. See Grinding Wheel Bushings.

Busses. A term sometimes applied to bus-bars. See Bus-Bars.

Butt Joint. A joint made either by welding or riveting, in which the two ends of the plates joined are abutted squarely against each other without overlapping. In the case of the riveted butt joint, the two ends of the plate are usually riveted to two plate strips that straddle the joint above and below.

Button Locating Method. This is a method employed for accurately locating work such as jigs, etc., especially on the faceplate of a lathe. This method is so named because cylindrical bushings or buttons are attached to the work in positions corresponding to the holes to be bored, after which they are used in locating the work. These buttons, which are ordinarily about 1/2 or 5/8 inch in diameter, are ground and lapped to the same size, and the ends are finished perfectly square. After the buttons are all set in correct relation with each other and have been tightened, the work is mounted on the faceplate of the lathe, and one of the buttons is set true with the axis of the lathe by the use of a test indicator. This button is next removed; the hole is then drilled nearly to the required size, after which it is bored to the finish diameter. In a similar manner, the other buttons are set in the central position, one after another, and the holes bored. It is evident that if each button is correctly located and set perfectly true in the lathe, the various holes will be located at the required center-to-center dimensions within very close limits. When a precision jig-boring machine is available, the button method is not required.

Buttress Threads. Screw threads of the buttress type are designed to resist heavy axial loads in one direction. Diagram *A* shows a common form. The front or load-resisting face is perpendicular to the axis of the screw and the thread angle is 45 degrees. The pitch of the thread may be the same as for the



Screw Threads of the Buttress Type

American standard or the Whitworth standard. According to one rule, the pitch $P = 2 \times$ screw diameter $\div$ 15. The thread depth d may equal $3/4 \times$ pitch, making the flat $f = 1/8 \times$ pitch. Sometimes depth d is reduced to $2/3 \times$ pitch, making flat $f = 1/6 \times$ pitch.

Load-resisting Side Inclined: The load-resisting side or flank may be inclined an amount (diagram B) ranging usually from 1 to 5 degrees to avoid cutter interference in milling the thread. With an angle of 5 degrees and an included thread angle of 50 degrees, if the width of the flat f at both crest and root equals $1/8 \times$ pitch, then the thread depth equals $0.69 \times$ pitch or $3/4\ d_1$. Diagram C shows a buttress thread of the sharp vee form with a front face angle a of 1 degree; some flat or rounding, however, at the crest and root of any screw thread is preferable.

Saw-Tooth Thread: The saw-tooth form of thread illustrated by diagram D is known in Germany as the "Sägengewinde" and in Italy as the "Fillettatura a dente di Sega." Pitches are standardized from 2 millimeters up to 48 millimeters in the German and Italian specifications. The front face inclines 3 degrees from the perpendicular and the included angle is 33 degrees.

The thread depth d for the screw $= 0.86777 \times$ pitch P. The thread depth g for the nut $= 0.75 \times$ pitch. Dimension $h =$

$0.341 \times P$. The width f of flat at the crest of the thread on the screw $= 0.26384 \times$ pitch. Radius r at the root $= 0.12427 \times$ pitch. The clearance space e between the root of the screw thread and the crest of the nut $= 0.11777 \times$ pitch.

Butt-Welded Pipe. Skelp used in making butt-welded pipe comes from the rolling department of the steel mills with a specified length, width, and gage, according to the size of pipe for which it is ordered. The edges are slightly beveled with the face of the skelp, so that the surface of the plate which is to become the inside of the pipe is not quite as wide as that which forms the outside; thus when the edges are brought together they meet squarely. The skelp for all butt-welded pipe is heated uniformly to the welding temperature. The strips of steel, when properly heated, are seized by their ends with tongs and drawn from the furnaces through bell-shaped dies or "bells," as they are called. The inside of these bells is so curved that the plate is gradually formed in the shape of a tube, the edges being forced squarely together and welded. For some sizes, the pipe is drawn through two bells consecutively at one heat, one bell being just behind the other, the second one being of a slightly smaller diameter than the first.

The efficiency of a butt weld depends largely upon the relationship of the thickness to the diameter of the tube. The thickness should be sufficient to enable considerable pressure to be put upon the two butting edges without fear of buckling or overlapping of the material, but it must not be so thick that the stress required in putting sufficient pressure on the weld involves a pull on the tube which, after it leaves the ring, may reduce or break it. With the standard thickness of gas, water, and steam pipe, of the sizes to which this process is usually applied (1/8 to 1 1/2 inches for standard gas, water, and steam thicknesses of these sizes), these conditions are fulfilled, but with heavier pipes it is necessary to effect the welding in several successive passes through graded rings. The production of pipes by butt welding is usually restricted to sizes varying from about 1/4 to 2 inches, although pipes as large as 3 inches or even 4 inches have been made in this way. The usual commercial limit, however, is about 2 or 2 1/2 inches. When a very great resistance to inside pressure is required, or when it is essential to use comparatively thin metal, the butt-welding method is impracticable.

By-Pass Valves. When valves are of five or six inches in diameter and upward, and are used for live steam or water under considerable pressure, the type of valve having a by-pass is often used. The object of the by-pass is to equalize the pressure on each side of the valve, so that it can be opened more easily.

C

Cabinet File. A cabinet file is one that is flat on one side and rounded on the other, but which is wider and thinner than a regular half-round file. It is double-cut, with coarse, bastard teeth. This type is made for cabinet makers and wood-workers generally.

Cable. A cable, generally, is a hemp, Manila, or wire rope twisted together from a number of different strands.

Cable, Electric. In electrical engineering, a cable is defined by the Bureau of Standards as (1) a conductor of electric current, composed of a group of wires, usually twisted or braided together; or it may consist of (2) a combination of conductors insulated from one another, generally known as a "multiple-conductor" cable. The component conductors of the second kind of cable may be either solid or stranded, and this cable may or may not have a common insulating covering. The first kind of cable is a single conductor, while the second is a group of several conductors. The term "cable" is applied by some manufacturers to a solid wire heavily insulated and lead covered; this usage arises from the manner of the insulation, but such a conductor is not included under the Bureau of Standards' definition of "cable." Cable is a general term, but, in practice, it is usually applied only to the larger sizes. A small cable is called a "stranded wire" or a "cord." Cables may be bare or insulated, and the latter may be armored with lead, or with steel wires or bands.

A *coaxial cable* is one in which one conductor is a hollow tube and the other is supported by insulators inside the tube and along its axis. This type of cable is used for telephone and television transmission.

Cable-Laid Rope. A cable-laid wire rope is a compound rope consisting of several ropes laid together into one. A cable, for instance, may be made up of six ropes twisted together, each of the six ropes, in turn, consisting of six strands, each of which strands is composed of seven wires. Such a cable-laid rope would be described as a 6 by 6 by 7 rope or cable.

Cadmium. Cadmium is one of the metallic chemical elements which shows a close relationship to zinc. Its chemical symbol is

Cd, and its atomic weight, 112.4. The specific gravity of the pure metal is 8.56, but the commercial metal has a specific gravity of 8.6, on account of the greater density due to hammering. Cadmium resembles tin in color and general appearance. It does not occur free in nature, but is commonly found associated with zinc in zinc-blende and other zinc ores, and the commercial metal is obtained from the smelting of zinc ores. It is obtained mainly from Silesia and Belgium. Its most important use is in combinations with such metals as lead, tin, and bismuth with which it forms alloys that fuse at very low temperatures. One of these alloys, containing 50 per cent of bismuth, 25 per cent of lead, 12.5 per cent of tin, and 12.5 per cent of cadmium, melts at a temperature of 149 degrees F. Cadmium sulphate is also used for making standard electric cells.

Cadmium Effect on Copper. Copper wire containing a small amount of cadmium has a greater tensile strength and a higher resistance to abrasion than ordinary copper wire, while its electrical conductivity is reduced very little, or less than 1 per cent for each 0.1 per cent of cadmium. The tensile strength increases slowly with increasing cadmium content, until 0.6 per cent of cadmium is reached; beyond this point additions of cadmium cause very rapid increases in tensile strength. Copper wire with 1 per cent of cadmium has been subjected to a temperature of 260 degrees C. for thirty minutes without showing signs of softening. A cadmium-copper wire having 20 per cent greater tensile strength has also 75 per cent greater resistance to breaking after repeated bendings than pure copper wire. In tests made with trolley wires under working conditions, the loss in diameter after eight months' use was less than one-third that recorded for pure copper wire.

Cadmium Solder. Cadmium solders may be used for soldering tin plate, terneplate, brass, and copper, according to an investigation made by the Bureau of Standards. Four different compositions of cadmium solders have been tried: (1) Lead, 90 per cent; cadmium, 10 per cent; (2) lead, 80 per cent; cadmium, 10 per cent; tin, 10 per cent; (3) lead, 85 per cent; cadmium 10 per cent; tin, 5 per cent; (4) lead, 75 per cent; cadmium. 10 per cent; tin, 15 per cent. The manufacture and use of the alloy first mentioned is rather difficult, because it oxidizes easily in the molten condition. The best composition is said to be that containing 80 per cent of lead and 10 per cent each of cadmium and tin.

Caesium. A rare, strongly basic metallic element, the chemical symbol of which is Cs, and the atomic weight, 132.8. It

melts at 26 degrees C. (79 degrees F.), and has a specific gravity of 1.88. It is silver-white in appearance.

Calcination. The process of calcination is used in metallurgy for expelling, by means of heat, volatile matters with which metals are combined in their ores, thus reducing them, generally, to an oxide. The process is also frequently known as *roasting*. In the metallurgy of many of the most common metals, like copper, calcination or roasting is the first process to which the ore is subjected.

Calcium. Calcium is one of the metallic chemical elements. Its symbol is Ca, and its atomic weight, 40.1. Its specific gravity is 1.57, making its weight per cubic inch 0.057 pound. Calcium melts at a temperature of 810 degrees C. (1490 degrees F.). Its electrical conductivity (silver = 100) is 21.8. Calcium is a metal having a light yellow color and brilliant luster. It is about as hard as gold and is very ductile. It oxidizes rapidly in moist air, and burns at a red heat. A freshly cut surface of the metal closely resembles zinc in appearance, but when tarnished by exposure to the air it becomes yellow, and finally grayish-white. It combines directly with most elements, including nitrogen, and this is taken advantage of in forming an almost perfect vacuum. The metal is generally prepared by electrolysis. The most important industrial use of calcium is in the form of calcium carbide (CaC_2), which is the source of acetylene. Calcium carbide is manufactured by heating lime and carbon in the electric furnace.

Calcium Carbide. Calcium carbide (CaC_2) is a chemical composition of considerable industrial importance on account of the fact that it is used to produce acetylene gas through the action of water upon the carbide, and, hence, it is an important factor in the autogenous welding industry. Calcium carbide is produced in the electric furnace, the raw materials being lime and anthracite in the proportion of 100 parts, by weight, of lime to 68 parts, by weight, of anthracite. About 1.8 pounds of this mixture is required to produce one pound of calcium carbide. Two processes are in use for producing the compound by means of the electric furnace, one being known as the *ingot* process and the other as the *tapping* process.

Calcium Carbonate. This is commonly known as "carbonate of lime," and is found generally in the form of limestone, marble or chalk. Its specific gravity is 2.8. When contained in the feed water for boilers, it forms a soft mud in the boilers, unless cemented into a scale by the presence of calcium sulphate. It also forms a hard scale in economizers when the water is at a

comparatively low temperature. It is soluble in water containing carbon dioxide, and is more easily dissolved in cold than in hot water.

Calcium carbonate, also known as *whiting*, is used for paints for the protection of iron and steel against corrosion. It is extensively used in paints, partly because it neutralizes any free acid that may be present in the linseed oil. When produced by artificial means, it generally contains impurities, requires more oil for grinding, and has not a high protective value.

Calcium Chloride. A compound which, when present in boiler feed water, has a corrosive effect and which is one of the causes of *pitting* in boilers.

Calcium Light. A very intense white light produced by two streams of gas, one of oxygen and one of hydrogen, impinged upon lime, while ignited.

Calcium Sulphate. Calcium sulphate, more commonly known as *gypsum* or *plaster-of-paris*, is a sulphate of lime soluble in water free from carbonic acid at moderately low temperatures. When present in boiler feed water, it causes a hard scale difficult to remove. Mixed with mud or the sludge from *calcium carbonate*, it also forms a hard scale. Calcium sulphate is widely used in the making of paints, but its use should be avoided in paints used for the protection of iron and steel against corrosion, because it is somewhat soluble in water and has a tendency to be washed off, and may, for this reason, even promote corrosion.

Calibration. Calibration, in its mechanical sense, denotes an accurate comparison of any measuring instrument with a standard, and more particularly the determination of the errors of a scale used in a measuring device. The method used in calibrating any measuring instrument is generally divisible into two parts, of which one or the other may often be omitted. The first step is to determine the value of the unit to which the measurements are referred, by comparison with a standard unit of the same kind. This part is known as the "standardization" of the instrument, or the determination of a "reduction factor." The second step consists in the verification of the accuracy of the subdivision of the scale of the instrument, which is the actual calibration of the scale, and which does not necessarily involve a comparison of the instrument with any independent standard, but merely a determination of the relative accuracy of the graduations. In many cases, the process of calibration consists of a comparison of the instrument to be tested with a standard, covering the whole range of the graduations on the standard, the relative values of the subdivisions of the standard itself having been previously tested.

The usual method of calibration is the direct comparison of an instrument with a standard over the whole range of its scale. The standard itself should be previously calibrated so that its accuracy, or the amount of its errors, is known. The term "calibration" refers not only to measurements of length, but to measurements of all other engineering units; thus, for example, ammeters, voltmeters, pyrometers, dynamometers, and all other measuring instruments, are calibrated by a comparison with a standard.

Caliper, Gear Tooth. See Gear Tooth Caliper.

Calipers. Calipers are measuring tools used for taking measurements in machine work, and employed especially for measurements not requiring great accuracy. The ordinary machinist's calipers consist simply of two arms or legs joined with a pivot at one end and provided with points at the other end suitable for the kind of measurement, whether external or internal, that is to be made. Measurements are taken by comparing the caliper setting with the graduations of a scale.

Calite. Calite, an alloy containing iron, chromium, nickel, and aluminum, is the result of experiments conducted by metallurgists of the General Electric Co., for the purpose of finding an alloy that would withstand high temperatures, could be quenched repeatedly, and would be highly resistant to oxidation. Annealing boxes made from calite have been run for 1500 heat-hours with out warpage, growth, or failure. The metal runs freely wher molten, and any casting which can be made of steel can also be produced from this alloy. Sections as low as 3/16 inch in thickness have been successfully cast. Calite cannot be machined in the cast condition nor cut with an oxyacetylene torch; hence, it must be finished by grinding.

This alloy is said to resist oxidation up to about 2375 degrees F., but a working temperature of 2200 degrees is recommended. Calite is practically non-corrosive, samples having been polished and subjected to a spray of saturated sea-salt solution at 100 degrees F. for 200 hours without any effect on the polish. The physical properties are: Melting point, 2780 degrees F.: softening temperature, 2500 degrees F.; specific gravity, 7.03; weight per cubic inch, 0.25 pound; and tensile strength, 36,800 pounds per square inch.

Calite Alloys. The Calite alloys are a group of heat-enduring alloys available in the form of castings, sheets, shapes and forgings with particular reference to commercial requirements. Calite "A" is a nickel-chromium alloy available in cast form only and intended for general heat-enduring applications up to maximum metal temperatures of 2000 degrees F. The metal is readily machinable and entirely resistant to corrosion in contact with the

ordinary products of combustion. Calite "B" is a nickel-chromium-aluminum alloy available in cast form only and intended for heat-enduring applications up to maximum metal temperatures of 1800 degrees F. This alloy was developed for the fabrication of beams and other parts required to sustain a load at high temperatures. It is unique in its quality of extreme stiffness at all temperatures up to the maximum safe working limit. The alloy is entirely resistant to corrosion in contact with the ordinary products of combustion. It can not be machined. Calite "E" is a malleable nickel-chromium alloy available in the form of castings, sheets, shapes and forgings. In addition to immunity from oxidation up to maximum metal temperatures of 1800 degrees F., it is not affected by weather corrosion, sulphur compounds and many organic acids and inorganic salts. The alloy finds wide application in sheet form. Sheets may be readily flanged, punched or welded. The welding operation may be successfully performed either with gas or electric arc. Calite "N" is a nickel-chromium alloy available in both cast and rolled form. The alloy is immune to oxidation up to maximum metal temperatures of 2000 degrees F., its chief application being in sheet form. Calite "S" is a malleable chromium-iron alloy available in the form of castings, sheets, shapes and forgings. In addition to immunity from oxidation up to maximum metal temperatures of 1650 degrees F., it is not affected by weather corrosion or by corrosion in contact with nitric acid, sulphur compounds, alkaline solutions and many organic acids. The alloy finds wide application in sheet form.

Calking. The riveted joints of steam boilers and other vessels which subjected to pressure are made tight by "upsetting" and compressing the metal along the edges of the joint, which operation is known as *calking*. The calking tool by means of which the material is compressed is either operated by a pneumatic hammer or, if such a tool is not available, it is struck repeatedly by a hand hammer. As the edge is driven back and upset, the lap extending beyond the rivet is sprung somewhat and reacts against the lower plate with sufficient intensity to prevent the gas or fluid under pressure from passing the calked edge. The calking end of the tool used is rounded, and the radius of curvature should be somewhat proportional to the thickness of the plate to be calked, the radius increasing as the thickness of the plate increases. The edge of a plate that is to be calked should be fairly smooth and even, and should also be slightly beveled so that the lower edge which is next to the seam projects out somewhat. The angle to which the edge is beveled, varies in different shops, and, in some places, it is gaged merely by the eye, whereas, in others, templets are used. This angle, as

measured from the inner or joint side of the sheet, usually varies from 75 to 80 degrees. The heavier form of pneumatic hammers are recommended for calking, in order to secure heavy blows and a more solid connection between the two sheets.

Calorie. The metric unit of quantity of heat, also known as the *French thermal unit,* or the *kilogram-calorie,* is the quantity of heat required to raise the temperature of one kilogram of pure water one degree C. One kilogram-calorie = 3.968 British thermal units. One British thermal unit = 0.252 kilogram-calorie. The British thermal unit (B.T.U.) is the quantity of heat required to raise the temperature of one pound of pure water one degree F.

Calorific Value of Fuel. See Combustion of Coal.

Calorimeters. Calorimeters are of two kinds, fuel calorimeters and steam calorimeters. Fuel calorimeters are used for determining the heating value of fuels. Steam calorimeters are used for determining the percentage of moisture in steam. A *fuel calorimeter* consists mainly of a closed chamber in which a previously weighed sample of the fuel can be rapidly and completely burned. A receptacle containing a predetermined amount of water surrounds this chamber, so that the heat produced by the combustion of the fuel is transferred to the water. A sensitive thermometer is then used for measuring the rise in temperature of the water. Special means must be provided for igniting the fuel, and provision must be made for preventing loss of heat from the calorimeter by radiation or by the escape of the heated gases of combustion. The most commonly used calorimeter is that known as a "bomb calorimeter," also called "Mahler's modification of Berthelot's calorimeter."

Steam calorimeters are constructed in a number of different ways; one of those most commonly used consists of a half-inch pipe closed at one end and perforated with several ⅛-inch holes in its walls. This pipe is inserted into the main steam pipe so that the steam can enter through the small holes. The other end of the pipe is throttled by an orifice 1/16 inch in diameter, through which the steam escapes into a chamber having an outlet to the atmosphere. The temperature and pressure of the steam on each side of the orifice are then observed. The action of the instrument depends upon the fact that the heat of saturated steam increases with the pressure, and, consequently, if the pressure is reduced by the throttling effect of the orifice, the heat liberated will convert the moisture into steam and produce super-heating. The steam in the chamber mentioned is superheated according to the amount of moisture contained in the steam passing into the half-inch pipe from the main steam pipe.

Calorimetric Pyrometers. In calorimetric pyrometers, the total heat absorbed by a metal—platinum, in the laboratory, and nickel or copper, in industrial works—is used to indicate the temperature. This was an early form of pyrometer.

Calorizing. Calorizing is a process for covering metals with a layer of alumina, so that the metal can be heated to a comparatively high temperature—dull red heat—without oxidizing and deteriorating. Calorizing is used, among other things, for copper soldering irons, and for iron resistance wires for electric heating devices. It is intended only for protection at high temperatures and does not take the place of galvanizing, sherardizing, or similar processes for the protection of iron against oxygen or corrosion at low temperatures. Its usefulness lies within a range of temperatures which are much higher than those to which a galvanized or sherardized coating could be exposed.

Camelia Metal. A bearing metal composed of 70 per cent of copper, 15 per cent of lead, 10 per cent of zinc, 4.5 per cent of tin, and 0.5 per cent of iron is known as "Camelia" metal. It belongs in the same class as Ajax plastic bronze and brasses used for railroad car bearings.

Cams. Many machine parts require either an intermittent or an irregular motion. The most common method of obtaining an irregular motion is by means of cams which have grooves or surfaces of such shape or form that the required motion is imparted to the driven member when the cam is in motion. The exact movement derived from any cam depends upon the shape of its operating groove or edge, which may be designed according to the motion required.

Cams may be classified according to the relative movements of the cam and follower and also according to the motion of the follower itself. In one general class may be included those cams which move or revolve either in the same plane as the follower or a parallel plane, and in a second general class, those cams which cause the follower to move in a different plane which ordinarily is perpendicular to the plane of the motion of the cam. The follower of a cam belonging to either class may either move in a straight line or receive a swinging motion about a shaft or bearing. The follower may also have either a uniform motion or a uniformly accelerated motion.

The working edge or groove of a uniform motion cam is so shaped that the follower moves at the same velocity from the beginning to the end of the stroke. Such cams are only adapted to comparatively slow speeds, owing to the shock resulting from the sudden movement of the follower at the beginning of the stroke and the abrupt way in which the motion is stopped at

the end of the stroke. If the cam is to rotate quite rapidly, the speed of the follower should be slow at first and be accelerated at a uniform rate until the maximum speed is attained, after which the motion of the follower should be uniformly decreased until motion ceases, or a reversal takes place; such cams are known as "uniformly accelerated motion cams."

Types of Cams: Cams may be divided, according to their mechanical construction, into three different types—plate cams, face cams, and cylinder cams. *Plate cams,* also known as *disk* or *peripheral cams,* are those cams which consist of a flat disk, and on which the follower operates against the outside or peripheral surface of the disk. A well-known type of this form is the *heart cam,* so called because of its peculiar shape. The *face cam* also consists of a flat disk, but the follower, instead of operating against the outside periphery of the disk, engages a groove cut into the flat surfaces of the cam. *Cylinder cams,* also known as *barrel cams,* are cylindrical in shape; the follower engages a groove cut into the cylindrical surface of the cam. Either of these types of cams may be designed to produce a uniform or a uniformly accelerated motion, or may produce any irregular motion required. The type of cam, as regards uniformity of motion, depends upon the dynamic conditions; but the form of cam, whether a plate cam, face cam, or cylinder cam, depends entirely upon the designer's judgment as to the best mechanical means of obtaining the desired movement. See Gravity Curve; Harmonic Motion Curve.

Cams, Grinding. The cams used on gas and gasoline motors, for operating the inlet and exhaust valves, are finished to the correct form by grinding. This grinding may be done in a regular cylindrical grinding machine by using a suitable cam-grinding attachment. The general method of grinding cams is by so mounting the cam or camshaft that, while rotating, it will be moved toward and from the grinding wheel by a master cam, the movement causing the cam to be ground to the required form or contour. The master cam is in engagement with a roller which transmits motion to the work-holding fixture. It is evident that cam grinding first involves the generation of master cams, since these must be made to suit each different form of cam that is ground.

Cams, Milling. Most cams are milled by using either an attachment on a milling machine or a special cam-cutting machine, the arrangement in either case being such that the contour of a master cam or templet serves to control the curvature of the cam groove that is milled. The curvature of the master cam groove or templet may or may not be an exact duplicate of the cam

that is cut, as this depends upon the design of the cam-cutting mechanism.

Cam Milling Machine: Cam or form milling machines operate on the same general principle as an ordinary profiling machine, although the construction is different. When a machine of this type is in operation, a pen or roller bears against a former plate or model, and, as the work table revolves, the cutter is caused to move so as to reproduce the required outline on the work. The master cam is rotated in whichever direction presents the least abrupt angles for the roller and cutter to pass over. For instance, if a cam were being milled having a sudden rise at one point, the direction of rotation should be such that the former pin will approach the rise from that side which has the most gradual ascent.

Canadian Corundum. A natural abrasive containing from 90 to 95 per cent of crystalline alumina, which constitutes the cutting material of the abrasive. As an abrasive it is much better than emery, containing less iron oxide, which is the most objectionable impurity. Canadian corundum is mined in eastern Ontario, where there are very large and practically inexhaustible deposits.

Candlepower. The lighting effect of a source of light is measured or expressed in candlepower. A "candle" is the unit of light intensity. The unit used in the United States is a specified fraction of the average horizontal candlepower of a group of 45 carbon-filament lamps preserved at the Bureau of Standards, when the lamps are operated at specified voltages. This unit is identical, within the limits of uncertainty of measurement, with the International Candle established in 1909 by agreement between the national standardizing laboratories of France, Great Britain, and the United States, and adopted in 1921 by the International Commission on Illumination.

The maintenance of the adopted unit by means of incandescent lamps is a temporary expedient, pending the development of a satisfactory reproducible primary standard. It is expected that eventually the unit will be defined as a fraction of the luminous intensity of a black-body radiator under specified conditions.

Distinction is made between the *mean horizontal candlepower* of a lamp, which is the average candlepower in a horizontal plane passing through the luminous center of the lamp when mounted in the usual manner, as, for example, in the case of an incandescent lamp with its axis of symmetry vertical; the *mean spherical candlepower* of a lamp, which is the average candlepower of the lamp in all directions; and the *mean hemispherical candlepower* of a lamp, which is the average candlepower of the lamp

in either the upper or the lower hemisphere.

One candle will produce an illumination of one *foot-candle* on a surface which is one foot normal distance away.

Cannonite. Low-carbon chromium alloy having a higher tensile strength than ordinary cast iron and possessing exceptional wearing qualities. For sand-casting automobile brake-drums and centrifugally casting cylinder sleeves.

Cant-File. Cant-files and cant-saw files are files of triangular cross-section, and differ in cross-section as to their angles; the cant-file has 30, 30, and 120 degree angles and the cant-saw, 35, 35, and 110 degree angles. The cant-saw shape was formerly known as "lightening." It is used principally for filing cross-cut saws having N-shaped teeth.

Cantilever. A cantilever is a beam which is supported or held firmly at one end and which projects from its support so that the outer end is free and unsupported. Each half of a cantilever bridge, for example, is wholly supported from the abutments and towers at the ends of the span, and the arms that reach out from the towers do not, in any way, depend upon their connection with each other at the center to increase their carrying capacity. They are merely connected, but each arm or cantilever is so proportioned that it is able to carry the load on the bridge independently of the remainder of the structure.

Capacitance. The capacity or capacitance of an alternating electric circuit is the measure of the amount of electricity held by it when its terminals are at unit potential. A condenser is said to have unit capacity if unit current existing for one second produces unit difference of potential at its terminals. The practical unit of capacity is that of a condenser in which one ampere during one second produces one volt difference of potential; it is called a *farad.* One farad is an extremely large capacity, and, therefore, one-millionth of one farad, called *micro-farad,* is commonly used. The effect of capacity is directly opposite to self-induction.

Capacity. The expression "capacity" is used in a number of different meanings in science and engineering. The capacity for heat is the amount of heat required to raise the temperature of an object one degree; hence, the capacity for heat is equal to the product of the mass or weight of an object by its specific heat. Sometimes the capacity for heat is expressed in terms of the amount of water which would be raised one degree by the amount of heat in question.

The capacity of an air compressor equals the amount of *free air* in cubic feet which may be compressed to a given higher temperature in a unit of time.

In electrical engineering, capacity is used in the terms *power capacity* and *current capacity*, referring to the power or the current which a device can safely carry. The temperature rise in a conductor due to heat developed when an electric current flows through it, is one of the limiting factors of the current-carrying capacity of a conductor.

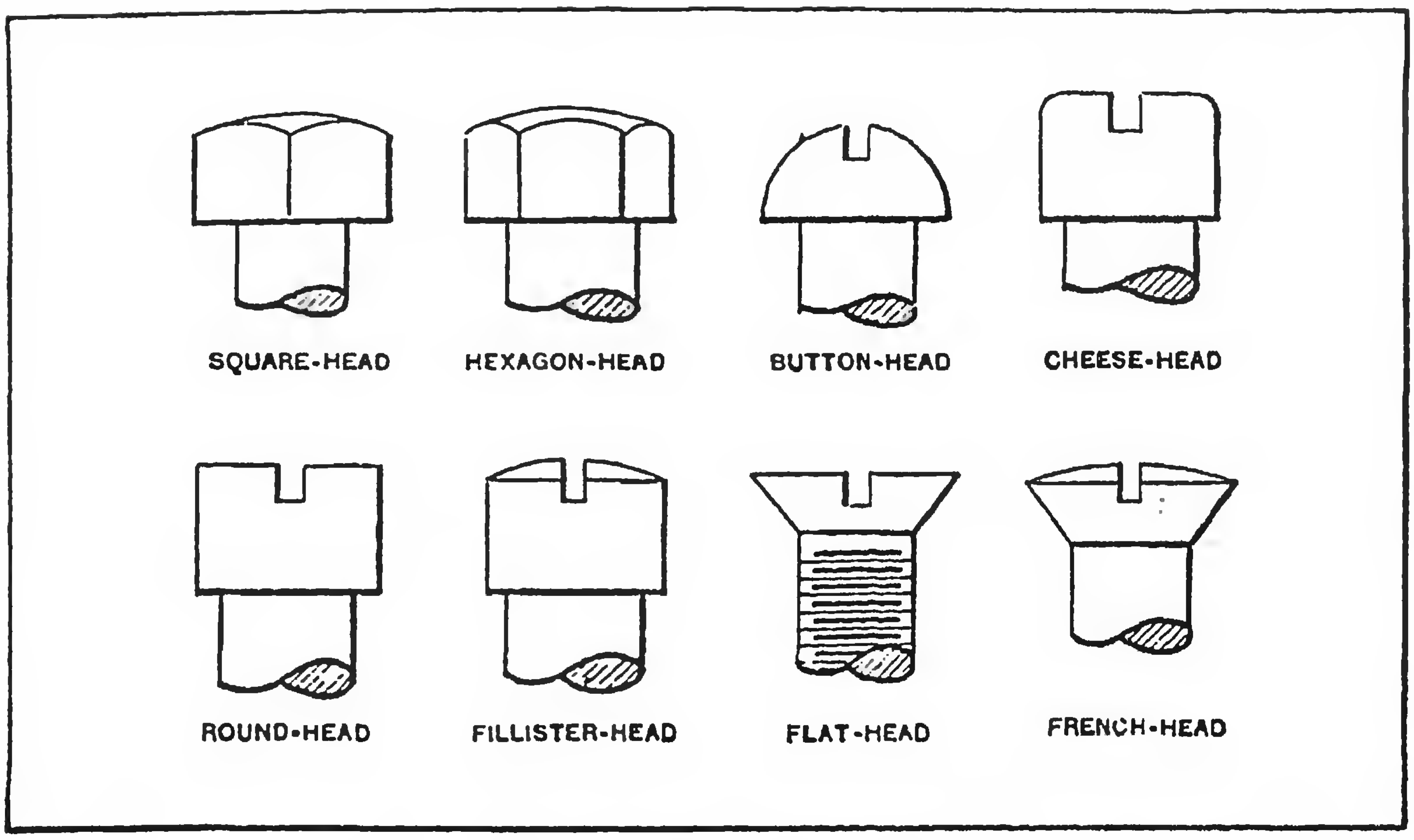
Capacity is also used when referring to the electrostatic capacity of a device, but it has been recommended by the American Institute of Electrical Engineers that, when used in this sense, the term *capacitance* be used instead. See also Capacitance.

Cape Chisel. A form of cold chisel having a narrow blade for the cutting of grooves or keyways. See Cold Chisels for illustration.

Capillary Action. When a tube of glass, the bore of which is very small in diameter and which is open at both ends, is placed vertically with its lower end immersed in water, the water will rise in the tube and will reach a higher level on the inside of the tube than the level of the water outside. The force or action which makes the water rise higher inside of the small-diameter tube is known as "capillary action." The same name is used for many other phenomena observed in the properties of liquids when spread over surfaces. Capillary actions are explained by reference to surface tension, cohesion, and adhesion between the molecules, etc. Capillary action is of importance in many devices used for lubrication, the oil rising against gravity along a wick and thereby reaching the surface to be lubricated.

Cap-Screws. Cap-screws usually are inserted into tapped holes like machine screws, but they are made in larger sizes and generally are used for heavier work. American standard hexagonal cap screws range in diameter from ¼ inch to 1¼ inches. Flat-head and button-head cap-screws range in diameter from ¼ to ¾ inch. Fillister-head cap-screws range from ¼ to 1 inch. The accompanying illustration shows some standard and special forms of heads. American standard cap-screws regularly are threaded to the coarse series of pitches. The thread length for the coarse thread series equals twice the diameter plus ¼ inch. The thread length for the fine series, according to the S.A.E. standard, equals one and one-half times the diameter plus ¼ inch. Cap-screws that are shorter than the thread length obtained by these diameters are threaded as close to the head as practicable.

Capstan Lathe. In England, turret lathes are often called *capstan lathes*. The terms "*capstan*" and "*turret*," however, are sometimes used interchangeably, although many firms observe a sharp distinction in their application, in that they apply the name "capstan" only to those machines which have a slide moving in



Names of Cap-screws

a saddle that is bolted down to the bed, whereas the name "turret" is used when the turret-slide is mounted directly on the bed. The effective difference between the two designs is that the working stroke of the first one is limited by the movement of the turret-slide in the saddle, whereas, with the second arrangement, the longitudinal feeding movement of the turret is limited by the length of the bed. See Turret Lathe Classification.

Carat. In reference to gold, a carat is an indication of how many 24ths of an alloy is pure gold. For example, 18-carat gold is an alloy containing 18/24 pure gold and 6/24 of other alloying metals. A carat is also a unit of weight used for diamonds and precious stones. The international carat, adopted 1905, and since then made standard in most European countries and, on July 1. 1913, in the United States, equals 200 milligrams or 3.086 grains troy. The South African carat is 3.174 grains. The old carat, standardized in 1877, was 205 milligrams or 3.163 grains troy.

Carbide Tools. Cemented or sintered carbides are used in the machine building and various other industries, chiefly for cutting tools but also for certain other tools or parts subject to considerable abrasion or wear. Carbide cutting tools, when properly selected to obtain the right combination of strength and hardness, are very effective in machining all classes of iron and steel, non-ferrous alloys, non-metallic materials, hard rub-

ber, synthetic resins, slate, marble, and other materials which would quickly dull steel tools either because of hardness or abrasive action. Carbide cutting tools are not only durable, but capable of exceptionally high cutting speeds.

Tungsten carbide is used extensively in cutting cast iron, nonferrous metals which form short chips in cutting; plastics and various other non-metallic materials. A grade having a hardness of 87.5 Rockwell A might be used where a strong grade is required, as for roughing cuts, whereas for light high-speed finishing or other cuts, a hardness of about 92 might be preferable. When tungsten carbide is applied to steel, craters or chip cavities are formed back of the cutting edge; hence other carbides have been developed which offer greater resistance to abrasion.

Tungsten-titanium carbide (often called "titanium carbide") is adapted to cutting either heat-treated or unheat-treated steels, cast steel, or any tough material which might form chip cavities. It is also applicable to bronzes, monel metal, aluminum alloys, etc. *Tungsten-tantalum carbide* or "tantalum carbide" cutting tools are also applicable to steels, bronzes or other tough materials. A hardness of 86.8 Rockwell A is recommended by one manufacturer for roughing steel, whereas a grade for finishing might have a hardness ranging from 88.8 to 91.5 Rockwell A.

Carbide of Silicon. A compound of silicon and carbide having the chemical formula SiC. See Abrasives.

Carbolite. The trade name "Carbolite" is used by the American Emery Wheel Works for silicon-carbide products. See Silicon Carbide.

Carbolon. The trade name "Carbolon" is used by the Exolon Company for silicon-carbide products. See Silicon Carbide.

Carbon. In nature, carbon is found free in two forms, as the diamond and as graphite; in combination with other elements carbon enters as a constituent of practically all animal and vegetable compounds, and of coal and petroleum. The specific gravity of carbon in the form of diamond is 3.5. When found as graphite, the specific gravity is about 2. Charcoal is also a porous form of nearly pure carbon. The properties of carbon vary according to the form in which it is found; thus, for example, the specific heat of diamond at 10 degrees C. (50 degrees F.) is about 0.11; of graphite at the same temperature it is about 0.16; and of wood-charcoal, 0.17. Besides the industrial uses of carbon in the form of graphite and charcoal, it is the chief constituent of all

combustible materials, and is one of the most important of the chemical elements in its combination with other elements. The carbon content of steel, for example, determines to a very large extent its characteristics. In fact, the distinction between wrought iron, mild steel, tool steel, and cast iron is due mainly to the different percentages of carbon contained in the metal.

Carbonate of Lime. Same as *calcium carbonate.*

Carbonate of Soda. Same as *sodium carbonate.*

Carbon-Break Circuit-Breaker. A device for automatically opening an electric circuit, so arranged that the arc is broken in the air between carbon blocks, although when closed most of the current is carried through copper contacts. Carbon is used because it withstands the heat of the arc without being destroyed, and the carbon contacts will not "freeze" together. Most air breakers are of this type.

Carbon Dioxide. A compound of carbon and oxygen, the chemical formula of which is CO_2.

Carbonia Finish. A carbonia finish consists of a method of coloring iron and steel surfaces with any of the temper colors that are obtainable by heating steel to different temperatures. The operation is carried out in a rotary gas furnace; the finish produced has a high luster.

Carbonic Acid. Same as *carbon dioxide.*

Carbonite. The trade name "Carbonite" is used by the General Abrasive Company for silicon-carbide products. See Silicon Carbide.

Carbonizing. A term often applied erroneously to carburizing. See Carburizing.

Carbon Resistor. Carbon resistors may be of the fixed or variable type. The latter, called rheostats, are composed of a number of carbon plates or granules to which varying degrees of pressure may be applied by turning a control dial or knob. Increased pressure on the carbon pile produces a greater number of contacts between the carbon particles and the total resistance of the rheostat is reduced. When pressure is reduced the opposite effect is obtained. Such rheostats provide almost stepless control, high overload capacity and a wide control range.

Carbon Steel. The expression "carbon steel" is often applied to tool steel containing no alloying metals, the term being used to distinguish such steel from alloy steels which contain tungsten, nickel, chromium, or other metals. These alloy steels also contain carbon and many to the same extent as "carbon steel"; hence, this

expression is not strictly correct in a chemical or metallurgical sense. The carbon content in steel is generally expressed by giving the percentage of carbon as, for example, 0.90 per cent carbon steel. This is also often expressed as "90-point" carbon steel.

Carbon "Points" in Steel: The point system used in specifying the carbon content of steel is based on the division of one per cent into one hundred parts; hence, "10 points carbon" means one-tenth of one per cent carbon and not 10 per cent. To express the carbon content in percentage in the case, say, of 50-point carbon steel, the expression should be "one-half per cent" carbon. The term "points" probably originated in an inversion of the reading of the decimal of one per cent; the decimal 0.40, for instance, was read "40-point" instead of "point 40" in order to emphasize.

Carbon Temper of Steel: The carbon temper of steel is a term applied by steel makers to indicate the proportion of carbon in the steel, the temper marks or numbers being arbitrarily selected so that their relation to the percentage of carbon varies with different makers. According to one system, the temper number indicates approximately the number of tenths of the carbon percentage; for example, No. 8 carbon temper designates steel containing about 0.80 per cent of carbon, while No. 14 carbon temper designates steel containing about 1.4 per cent of carbon.

Carbon Steel Heat-Treatment. See Heat-treatment of Carbon steel.

Carbon Temper. See under Carbon Steel.

Carbon Tool Steel Applications. Steel with a carbon content of from 0.65 to 0.80 per cent is suitable for shear blades, boiler snaps, and cups, hammers, stamping and pressing dies, and mining drills. Steel with a carbon content of from 0.81 to 0.95 per cent is suitable for hot and cold sets, chisels, dies, shear blades, mining drills, blacksmiths' tools, swages, flatteners, and set-hammers. Steel with a carbon content of from 0.96 to 1.10 per cent is suitable for small cold chisels, hot sets, small shear blades, large pincers, large taps, granite drills, trimming dies, turning tools, planer tools, drills, cutters, slotting and milling tools, mill picks, circular cutters, small shear blades, and threading dies. Steel with a carbon content of from 1.11 to 1.25 per cent is suitable for small milling cutters, small taps, drills, slotting and planing tools, wood-cutting tools, turning tools, and razors.

The best all-around tool steel contains from 0.90 to 1.10 per cent of carbon, and can be adapted to a wider range of uses than any other grade. For tools, generally, it gives the highest strength together with a high degree of hardness when heat-treated. It cannot, however, be welded easily. Steels containing up to 1.50 per cent of carbon are easily burnt, and are welded

only with great difficulty. They can, however, be hardened to an extreme hardness.

Carborite. The trade name "Carborite" is used by the Vitrified Wheel Company for silicon-carbide products. See Silicon Carbide.

Carborundum. "Carborundum," is the registered trade-mark of The Carborundum Company covering silicon carbide and other abrasive products made by it. This term is not properly used as a generic name for silicon carbide.

Carbowalt. The trade name "Carbowalt" is used by the Waltham Grinding Wheel Company for silicon-carbide products. See Silicon Carbide.

Carburetor. The purpose of the carburetor of a gasoline engine is to introduce into the current of air, entering the cylinder of the engine, a proper quantity of gasoline in such a manner that it will be completely evaporated and thoroughly mixed with the air. The devices for forming an explosive mixture from gasoline and air may be divided into two distinct groups. In the *spraying* or *atomizing* type of carburetor, which is used on gasoline engines for automobiles, motor boats, etc., the necessary quantity of gasoline for each charge of the engine is atomized by a valve and then sprayed into the inrushing air, which process, especially when the air has previously been heated, is so thorough that the mixture may be used immediately for charging the engine. In the *vaporizing* carburetor, which is the type largely used for stationary engines, the engine piston draws air directly through a gasoline storage tank, thus saturating it with gasoline vapor. Additional air must be drawn in before the vapor enters the engine cylinders, to form an explosive mixture.

Carburizers. Carburizers may be classed by their physical form as follows: (1) Powder materials, in which the generator and the energizer are in a powder form and are thus mixed together. (2) Pill materials, in which the generator and the energizer are in a powder form, but are held together by a binder which in itself may be either a generator or an energizer. (3) Pellet materials, in which the generator is a granule of solid carbonaceous material coated with an energizer by the help of a binder. (4) Pellet and powder materials, in which the generator is a granule of solid carbonaceous material, and the energizer is in the form of a powder. A certain per cent of the powder may also be a generator. Different combinations of the above four forms may be found, but no great value should be attached to claims for their importance. Two other mediums are still used to some extent for carburizing, namely, bone and leather. Bone is classed as a pellet material, with the exception that the en-

ergizer is contained in the bone in the form of ammonium carbonate. The ammonia fumes are quite noticeable when water is poured on red hot bone. Leather is classed as a powder material due to its being so easily powdered. The energizer is in the form of cyanogen and is contained within the leather. Charcoal, coke and coal should not be classed as carburizers, as they are nothing more than generators. Alone, they are not easily controlled as regards penetration and percentages of carbon entering the steel to form the case. There are many commercial carburizers on the market in which the materials used as the generator may be hard and soft wood charcoal, animal charcoal, coke, coal, beans and nuts, bone and leather, or various combinations of these. The energizers may be barium, cyanogen, and ammonium compounds, various salts, soda ash, or lime and oil hydrocarbons. Sulphur and phosphorus are the two impurities that cause the greatest trouble in carburizing and are therefore the greatest drawbacks.

Carburizing. Carburizing, often erroneously known as "carbonizing," is generally referred to in connection with casehardening of steel. Carburizing consists in adding carbon to the surface of low-carbon steel by heating the steel in contact with materials high in carbon. The steel absorbs a certain amount of carbon from the carbonaceous materials, and this increase in the carbon content of the surface of the steel makes it possible to harden the steel in a manner similar to that in which so-called "high-carbon" steel is hardened, that is, by heating to a red heat and cooling by quenching.

To harden low-carbon steel involves two separate operations: First, the carburizing operation for impregnating the outer surface with sufficient carbon, and second, the heat-treating of the carburized parts so as to obtain a hard outer case and, at the same time, give the "core" the required physical properties. The term *casehardening* is ordinarily used to indicate the complete process of carburizing and hardening, but it is often applied to indicate the heat-treatment after carburization.

Carburizing by Rotary Method. In carburizing by the rotary method, the work is contained in a slowly revolving retort, where it is heated and subjected to the action either of a carburizing gas or of a solid carburizer. The parts, when sufficiently heated, have an affinity for the carbon in the gas or in the carburizing material, as the case may be, and the slow rotation which exposes all surfaces, combined with accurate temperature regulation, insures uniform carbon penetration and comparatively rapid action. When a carburizing machine is supplied with the proper air and fuel conditions, its charge may be brought to a carburiz-

ing heat of 1650 degrees F. in from three-fourths to one hour's time, depending upon the size of the work. Actually carburization starts about the time the work reaches a low red heat. If heat controllers are used, it is customary and practical to start the computation of carbon penetration at the time that the heat controllers shut off the fuel.

The fuel ordinarily used for heating the work is gas, but oil may also be employed as the heating fuel. Gas is preferable, as it is cleaner, requires practically no burner attention, and auxiliary equipment, such as heat-controlling apparatus, storage facilities, etc., is less complicated and less expensive. Gas is also more flexible in regard to temperature variations. The oil-fired machines are satisfactory, but much depends upon the manipulation of the burners. As one of the primary agents in gas for carburizing is the illuminants, and as these illuminants vary with the manufacture of gas, it is often found that the best results are obtained from solid carburizers. Any carburizing agent that is suitable for pack-hardening is satisfactory. Oil hydro-carbon materials may be objectionable on account of the smoke. Barium energized materials, and those containing less than 3 per cent sodium carbonate, are desirable. A powder material carburizes as fast as the same material in pill form.

Card Pattern. A molding pattern with a number of individual patterns gated together so that several can be molded at once.

Card-Weight Pipe. A term used to designate standard or full-weight pipe, which has the standard thickness.

Carnot's Function. In thermo-dynamics, that function of temperature in Carnot's theory of heat which corresponds to the reciprocal of the absolute temperature.

Carriage Bolt. A bolt having an oval head in cross-section, beneath which the bolt is square for a short distance. The other end of the bolt is threaded for about twice its diameter for a square nut.

Cartridge Brass. The sheet brass used for making cartridge cases for rifles and other small arms has, according to A.S.T.M. Specifications B19-29, the following composition, in per cent: Copper, 68 to 71; lead, 0.07 max.; iron, 0.05 max.; other materials, 0.15 max.; zinc, remainder.

Cartridge Fuse. A cartridge fuse consists essentially of one or more strips of fusible metal enclosed in a fiber tube filled with a powdered insulating substance. This substance serves to ab-

sorb the heat liberated when the fuse is blown and condenses the vapor of the molten metal, breaking the continuity of the electric circuit.

Casehardening. In order to harden low-carbon steel it is necessary to increase the carbon content of the surface of the steel so that a thin outer "case" can be hardened by heating the steel to the hardening temperature and then quenching it. The process, therefore, involves two separate operations. The first is the *carburizing* operation for impregnating the outer surface with sufficient carbon, and the second operation is that of heat-treating the carburized parts so as to obtain a hard outer case and, at the same time, give the "core" the required physical properties. The term "casehardening" is ordinarily used to indicate the complete process of carburizing and hardening, but it is often applied to indicate the heat-treatment after carburization.

For certain uses, steel parts are required to resist wear and at the same time to be sufficiently tough to withstand shocks. Toughness and hardness, however, are two qualities which do not appear at their maximum at the same time in steel. In machine construction, articles which must have a perfectly hard surface, and yet be of such internal structure that there is no chance of their breaking when in use, can be made to greater advantage from a mild steel which is casehardened than by using an expensive high-class crucible steel.

Casehardening Process: In general, the casehardening process consists of packing steel articles made from a low-carbon steel in metal boxes or pots, with a carbonaceous compound surrounding the steel objects. The boxes or pots are sealed and placed in a carburizing oven or furnace maintained at a heat of from about 1650 to 1830 degrees F. for a length of time depending upon the extent of the carburizing action desired. The carbon from the carburizing compound will then be absorbed by the steel on the surfaces desired, and the low-carbon steel is converted into high-carbon steel at these portions, while the internal sections and the insulated parts of the object retain practically their original low-carbon content. The result is a steel of a dual structure, a high-carbon and a low-carbon steel in the same piece. The carburized steel may now be heat-treated by heating and quenching, in much the same way as high-carbon steel is hardened, in order to develop the properties of hardness and toughness; but as the steel is, in reality, two steels in one, one high-carbon and one low-carbon, the correct heat-treatment after carburizing includes two distinct processes, one suitable for the high-carbon portion or the "case," as it is generally termed, and one suitable for the low-carbon portion or core.

Rehardening: The method of heat-treatment varies according to the kind of steel used. In general, quenching from the pot and again rehardening at a temperature of from 1400 to 1450 degrees F. will serve the purpose of refining the case to a great extent and will likewise bring out the natural qualities and toughness of the initial steel or core. Cooling in the pot, rehardening at about the critical temperature of the core, and quenching (the critical temperature being from about 1550 to 1650 degrees F., depending upon the original carbon content of the steel), and rehardening at the critical temperature of the case (1400 to 1450 degrees F.) will serve to refine the core and case to the maximum extent. The result will be maximum toughness and grain refinement of core, and maximum toughness, grain refinement, and hardness of the case. The function of cooling in the pot is to allow the structure of the steel to come to rest, which helps to prevent warpage from internal strains.

Cyanide Bath: Another method of casehardening is to immerse steel articles in a cyanide bath heated to about 1580 degrees F. This process is convenient and effective only on small articles and where the required depth is not more than from 0.005 to 0.015 inch, or where a mere surface hardening is wanted. This is a fast case-forming method, being accomplished in from ten to fifteen minutes. The outstanding disadvantage of this process is the impossibility of producing uniform cases. The parts that are deep in the melted bath do not receive the same depth of penetration as the parts near the surface because the evolution of the cyanide gases at or near the surface favors penetration.

Cyanide Process: Casehardening may be done either by dipping a cherry-red piece of steel or tool into a container of powdered cyanide salt, such as potassium cyanide, sodium cyanide, or ferro- and ferri-cyanides, or sprinkling the powdered salt on the red-hot steel surface, and putting the steel back in the fire. The casehardening produced in this way is superficial, and resistance to excessive wear cannot be expected.

Gas Process: In another method, carburizing gases are passed over a piece of steel heated in a retort. This process is applicable to parts that are intricate in design. The principle upon which this process is based is the casehardening of steel and iron-alloy articles in cyanogen gas evolved from a container filled with an alkali cyanide salt, heated by electrical energy or other means to accomplish the vaporization or boiling of the salt. The parts being treated are independently heated out of contact with the fused cyanide salt. The depth of penetration is a function of the uniformity of the temperature of the article treated and the duration of treatment. Nascent cyanogen gas has a speed of

penetration of four or five times that of carbon monoxide. Sodium cyanide melts at 1112 degrees F. and boils at 1472 degrees F. Thus, the temperature of the pot must not be less than the latter, and to absorb this gas effectively, the steel must be at a temperature above the upper critical point, or about 1650 degrees F. See Nitrogen Hardening.

Casehardening Carburizers. See Carburizers.

Casehardening Steel. A low-carbon steel containing, say, from 0.15 to 0.20 per cent of carbon is suitable for casehardening. In addition to straight carbon steels, the low-carbon alloy steels are employed. They add to the parts the same advantageous properties for which they are employed in other classes of steel. *Nickel* is a valuable aid in producing a core which readily responds to refining and at considerably lower heats than in steel in which it is absent. In some cases results have been obtained by a single heat-treatment which compare most favorably with straight carbon steel, given two heats, one for case and one for core. The core resulting has a fine grain and is extremely tough. *Chromium* gives a very fine grain to case and core and imparts additional hardness in conjunction with the carbon. It has, however, when present in an amount much over 0.25 per cent, a tendency to render the core less tough, especially in steels around 0.20 per cent carbon, or higher. *Chrome-nickel* steels containing both of these elements give very good results. They give very fine-grained parts after heat-treatment, and can be treated at a considerably lower temperature than straight carbon steels.

Casein Glue. See Glues for Wood.

Casing Thread. The standard casing thread of the American Petroleum Institute has an included angle of 60 degrees and a taper of ¾ inch per foot.

The fourteen casing sizes listed in the 1942 revision have outside diameters ranging from 4½ to 20 inches. All sizes have 8 threads per inch.

Rounded Thread Form: Threads for casing sizes up to 13⅜ inches, inclusive, have rounded crests and roots, and the depth, measured perpendicular to the axis of the pipe, equals $0.626 \times$ pitch $- 0.007 = 0.07125$ inch.

Truncated Form: Threads for the 16- and 20-inch casing sizes have flat crests and roots. The depth equals $0.760 \times$ pitch $=$ 0.0950 inch. This truncated form is designated in the A.P.I. Standard as a "sharp thread."

Casting. In casting, a part is formed either by pouring molten metal into a mold, as in making ordinary iron, steel or brass castings, or by forcing molten metal under pressure into a mold

or die as in die-casting. The term "casting" is applied both to the process and to the parts produced by it. See Aluminum Castings; Brass Alloys for Castings; Gear Castings, Bronze; Cast Iron; Chilled Castings; Cold-pressed Castings; Copper Castings; Malleable Castings; Steel Castings.

Casting, Centrifugal. See Centrifugal Casting.

Casting in Permanent Molds. A method for making castings by the use of what is termed permanent molds, is known as the *Custer process*. The molds are made of metal, and, hence, of a permanent nature, as compared with sand molds which disintegrate after each casting is made. The permanent molds should be made of a soft cast iron fairly high in silicon and graphite carbon, and low in combined carbon. A cast iron used for permanent molds is as follows: Combined carbon, 0.84 per cent; graphite carbon, 2.76 per cent; silicon, 2.02 per cent; sulphur, 0.07 per cent; phosphorus, 0.89 per cent; and manganese, 0.29 per cent.

The reason that it is possible to produce soft castings in a permanent metal mold is due to the fact that a certain time elapses between the point at which the molten metal will set and the temperature at which it will begin to chill. This interval is long enough to give the operator of the mold time to remove the casting from the mold before chilling begins. At this time the casting is still at a bright red heat, but the sudden contact with the cool surfaces of the mold has made the surface of the casting sufficiently hard so that it can be handled without fear of distortion or breakage.

"Casting-on" or "Burning-on." See "Burning-on" or "Casting-on."

Cast Iron. According to the specifications adopted by the International Association for Testing Materials, *cast iron* is defined as iron containing so much carbon that it is not malleable at any temperature. To conform to this definition, iron containing more than 2.2 per cent of carbon is classified as cast iron. Generally, commercial cast iron, however, has a carbon content of between 3 and 4 per cent. This carbon may be present as graphite, in which case the iron is known as *gray cast iron,* or it may be present in the form of cementite or combined carbon, in which case the iron is known as *white cast iron.* In most cases, however, carbon is present partly as graphite and partly as cementite. Besides carbon, silicon, sulphur, manganese, and phosphorus are nearly always present in cast iron. Cast iron is almost universally used for forms that must be shaped by casting, especially where weight is not objectionable, or where considerable weight

is desired. Ordinary cast iron should not be used for parts which are subject to shock or strain, as it is weak in tension and brittle. Cast iron makes a good bearing surface and is cheap. Surfaces of cast iron parts which are subject to continuous wear will last much longer if they are chilled.

Graphite Carbon: Graphite is merely mixed with the iron instead of being in chemical combination. Since it is only mixed with the metal, it cannot exert any direct influence upon the properties of the molecules of the iron. So far as the graphite itself is concerned, the toughness, hardness, and melting point of the grains of the iron will not be altered. The tensile strength will, however, be greatly affected, since the interposition of the flakes of graphite will act as partings between the grains of the metal and reduce the cohesion. Iron high in graphite is soft, and can be machined readily, but it is of low tensile strength.

Combined Carbon: The carbon which is in chemical combination affects directly and greatly the properties of ordinary cast iron. It is the principal factor in determining the hardness, tenacity, soundness, and freedom from internal stresses of the castings. In general, the percentage of combined carbon ranges from 0.05 in the softest cast iron to about 0.60 in iron of the highest strength. With suitable iron mixtures, the amount of silicon and sulphur present regulates the separation of carbon as graphite, so that the amount of silicon present is an index of the relation between the free and combined carbon. When the graphitic carbon is in excess, the fracture is grayish in color and the iron is known as *gray iron.* When the combined carbon is in excess, the fracture is either mottled or white, and is known as either mottled or *white iron.*

Cast Iron Properties: Ordinary cast iron generally is assumed to have an ultimate tensile strength of 18,000 to 22,000 pounds per square inch, an ultimate compressive strength of 80,000 to 100,000 pounds per square inch, an ultimate shearing strength of 18,000 to 25,000 pounds per square inch, and a modulus of elasticity of 12,000,000 to 16,000,000. Cast iron retains its strength of 100 per cent up to 400 degrees F., but falls from this point to 92 per cent at 750 degrees F. and 42 per cent at 1100 degrees F. The strength begins to decrease at about 500 degrees F. The specific gravity of cast iron is about 7.2, the weight per cubic inch being 0.26 pound. Cast iron melts at about 2300 degrees F. Its linear expansion per unit length, due to heat, per degree F. is 0.00000556. The physical properties of castings are influenced by the casting temperature, rate of cooling, etc., so that the probable strength and stiffness of a casting can be estimated only in a general way.

Cast Iron, Alloy Type. Alloy cast irons are used for various applications requiring strength and resistance to wear. Numerous compositions provide varying properties suitable for different classes of service. There are eight S.A.E. compositions used for such parts as cylinders, cylinder liners, brake-drums, sprockets, clutch plates, and pistons. These eight compositions contain from 2.80 to 3.40 total carbon; from 0.40 to 0.83 combined carbon; from 0.50 to 0.75 manganese; from 2 to 2.35 silicon. In addition, one or more of the alloying elements chromium, copper, molybdenum and nickel are used, but the kinds and amounts of these alloying elements are not specified because of specific service requirements, variations in foundry practice, possible variations in combinations of the alloying constituents. The tensile strength of alloy cast irons range for some applications from 35,000 to 45,000 pounds per square inch, and from 55,000 to 65,000 for classes of service requiring greater strength.

Nickel-Chromium Cast Iron: A corrosion- and heat-resistant cast iron having the same coefficient of expansion as plain cast iron at elevated temperatures consists of 28 to 32 per cent nickel, 4 to 5 per cent chromium, and the remainder cast iron. It is very tough, is machinable, and maintains its properties without deterioration at high temperatures. The hardness is from 140 to 240 Brinell, and the tensile strength is approximately 30,000 pounds per square inch. This metal is intended for use in contact with plain cast iron or steel—for example, as a liner or insert—where it will attain a higher temperature than its surroundings, and must pass through the heating and cooling cycles without becoming separated from the base metal that surrounds it. Examples of its application are bushings and liners for pumps and compressors that handle hot liquids or vapors and automobile-engine valve-seat inserts.

Cast-Iron Growth. The "growth" of cast iron is a peculiarity of certain kinds of cast iron to increase in size after repeated heatings. Cast-iron annealing ovens, 8 feet in length, which are kept red hot for prolonged periods between which they are permitted to cool off, sometimes grow to 9 feet in length in the course of their use. Cast-iron furnace grates, range fittings, etc., subjected to alternate heating and cooling are also frequently distorted and sometimes broken from the same cause. To avoid "growth" as much as possible, white cast iron should be used, which has a carbon content of about 3 per cent, and which is as free from silicon and other impurities as possible.

In a series of experiments by A. E. Outerbridge, Jr., for determining the growth of cast iron and its causes, a cast-iron bar of 1 by 1-inch section, 14 13/16 inches in length, was heated

27 times to about 1470 degrees F. for one hour. During this treatment it increased in size to 16½ inches length and 1⅛ by 1⅛-inch cross-section. This corresponds to an expansion of nearly 41 per cent. The enlarged bar had the same weight as the bar before the treatment. Twelve additional heatings increased the dimensions of the bar until the total expansion was 46 per cent.

Cast Iron, Nichrome In. See under Nichrome.

Cast-Iron Pipe. See Pipe.

Cast Steel. The term "cast steel" is sometimes used to designate what is known as tool steel or crucible steel, but this usage is becoming more and more obsolete and should be discontinued, as it is confusing. Steel castings made by pouring molten steel into suitable molds are sometimes referred to as cast steel, but the latter term should not be applied to the high-carbon steel which is made by the crucible or electric processes and is suitable for cutting tools.

Cast Welding. A process for welding together parts, usually of metals with a comparatively low melting point, by preparing a mold around the parts to be joined and pouring molten metal between them.

Catalytic Agent. A substance present in a chemical reaction which does not take a direct part in the reaction, but which remains the same throughout, or is only temporarily affected; this agent may accelerate or retard the rate at which the reaction takes place.

Catenary Curve. The *catenary* is the curve assumed by a string or chain of uniform weight hanging freely between two supports. The cables of a suspension bridge, if uniformly loaded, assume the form of the catenary curve. It has, therefore, considerable importance in structural engineering.

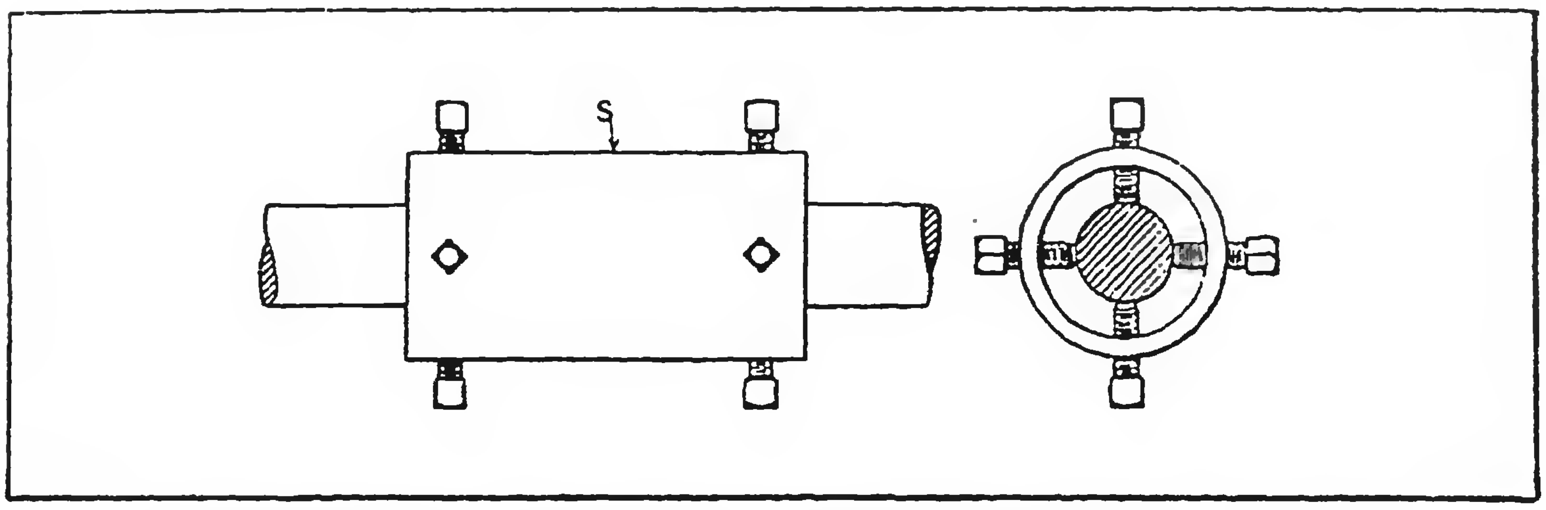
Cathode. The electrodes by means of which current enters and leaves any conductor of the non-metallic class, such as an electrolyte, are known as *anode* and *cathode*, respectively. A cathode is an electrode through which current leaves any conductor of the non-metallic class. Specifically an electrolytic cathode is an electrode at which positive ions are electrically discharged, or negative ions are formed, or at which other reducing reactions occur. See also Anode.

The heated, incandescent filament in a vacuum tube which emits a stream of electrons is designated as a *cathode*. Where the electrons emitted are formed into a directed "beam" as in an oscillograph or television type of vacuum tube, such an electronic "beam" is called a *cathode ray*.

Cat-Head. A device used in a lathe when it is required to apply a steadyrest to a surface that does not run true and which is not to be turned. This is simply a sleeve *S* (see illustration) which is placed over the untrue surface to serve as a bearing for the steadyrest. The sleeve is made to run true by adjusting the four set-screws at each end, and the jaws of the steadyrest are set against it, thus supporting the work.

Cecolloy. A nickel-molybdenum, air-furnace iron alloy having a fine homogeneous grain structure and a tensile strength of from 40,000 to 60,000 pounds per square inch. Suitable for making large castings weighing up to 50 tons. Used for forming dies, beds of heavy-duty machines, steam cylinder liners and rings, crushing machinery, etc.

Cecostamp. This is the trade name applied to an air-operated impact-type of stamping machine for embossing and shallow forming operations when inexpensive dies will produce the



Cat-head which is sometimes used as a Steadyrest Bearing

quantity of parts required. These dies may be made of lead and zinc cast in a plaster mold. Dies of aluminum, magnesium or wood are also used. The Cecostamp is intended for difficult forming of high-strength metals, such as stainless steel and certain aluminum alloys, and for hot-forming thin work that cools quickly. The successive blows may easily be controlled manually when variable blows are required or the machine may be set for uniform blows and continuous operation. An important application of impact stamping is in aircraft plants.

Cellucraft. A plastic coating for metal, wood, and rubber, applied by spray guns; available in bright colors, pastel shades, "metal tones," and other effects, obtained by pigmenting the coating material. A similar material known as "Macoid" is ap-

plied by dipping. Applicable to the finishing of automobile hardware, such as window regulators, door handles, and control knobs; die-castings in general; and molded rubber steering wheels.

Celluloid. Celluloid is a dried solution of gun-cotton (pyrrolin) and oil. It may be machined or molded into any form by softening it in boiling water. It is highly combustible and gives off extremely poisonous fumes when burning. It is only slightly affected by moisture but is soluble in alcohol. Celluloid is a good electrical insulating material, although its insulation qualities are greatly reduced at high temperatures. It can be easily molded at 100 degrees C., is highly elastic, and has considerable tensile strength.

Celluloid Bonding Process. Grinding wheels made by the celluloid process have a bond of celluloid, as the name implies. The abrasive grains are mixed with celluloid and this mixture is rolled into sheets from which the wheels are cut. After seasoning for several months, the wheels are ready to finish.

Celsius Thermometer. See Centigrade Thermometer.

Cement. The cements generally used in engineering construction are of three kinds, Portland, natural, and Pozzuolanic (slag) cements. The most reliable of these is the Portland cement, and this kind should always be used in reinforced concrete construction. See Portland Cement.

Cementite. Cementite is a carbide of iron having the chemical formula Fe_3C. Steel which has cooled slowly from a high temperature contains ferrite, cementite and pearlite, in relative proportions which vary according to the chemical composition of the steel. See Steels.

Cement, Mica and Steel. A gum and plaster-of-paris cement that has good adhesive qualities for attaching mica to steel is made by dissolving 1½ ounces of gum acacia in a half pint of boiling water and adding sufficient plaster-of-paris to form a paste. The materials to which the cement is applied should be pressed together as tightly as possible, in order to squeeze out the air bubbles.

Litharge, lead, and varnish form a good adhesive by mixing two parts of litharge and one part of white lead, and working them into a pasty condition by using three parts of boiled linseed oil and one part of copal varnish.

Cements for Joints. A strong cement which is oilproof, waterproof, and acid-proof, consists of a stiff paste of glycerin and litharge. These form a chemical combination which sets in a few minutes. If a little water is added, it sets more slowly,

which is often an advantage. This cement is mixed when required for use.

Mixture for Threaded Pipe Joints: A good material to apply to pipe threads before making up the joints, in order to obtain a tight joint that will resist the action of gases or liquids, is made of red lead mixed with pure boiled linseed oil. This mixture has been widely used and is very satisfactory. It should have a heavy fluid-like consistency, and if applied to a clean, well-cut thread will give an excellent joint.

Shellac for Pipe Connections: Shellac has proved to be a very satisfactory substitute for lead in sealing air and gas pipe connections. It is applied with a brush to the joints and hardens very rapidly, and being brittle, the pipes can be readily disconnected.

Graphite, Litharge, Chalk Cement: A good cement for use in making steam pipe joints is made in the following manner: Grind and wash in clean cold water 15 parts of chalk and 50 parts of graphite; mix the two together thoroughly and allow to dry. When dry regrind to a fine powder, to which add 20 parts of ground litharge and mix to a stiff paste with 15 parts of boiled linseed oil. The preparation may be set aside for future use, as it will remain plastic for a long time, if placed in a cool place. It is applied to the joint packing as any ordinary cement.

Sulphur, Graphite, Lime Cement: To make cement for steam, air and gas pipes, mix thoroughly powdered graphite, 6 parts; slaked lime, 3 parts; sulphur, 8 parts, and boiled oil, 7 parts. The materials must be thoroughly mixed by protracted kneading until perfectly smooth and free from lumps.

White and Red Lead Mixture: Mix in ordinary white lead, enough powdered red lead to make a paste the consistency of putty. Spread this mixture on the joint, and when it hardens, the joint will be water tight. This mixture was used on standpipe flanges after testing all kinds of rubber gaskets without success. The mixture hardened and make a tight joint, never leaking afterward.

Steam-tight Joints: Use white lead ground in oil and add to it as much black oxide of manganese as possible and a small portion of litharge. Knead with the hand, dusting the board with red lead. The mass is made into a small roll and screwed or pressed into position, the joint being first slightly oiled with linseed oil.

Cement for Steam and Water Pipes: A good cement for joints on steam or water pipes is made as follows: 10 pounds fine yellow ochre; 4 pounds ground litharge; 4 pounds paris white (whiting), and ½ pound of hemp cut up fine. Mix together thoroughly with linseed oil, to about the consistency of putty.

Mixture for Rust Joint: Mix 10 parts of iron filings, 3 parts chloride of lime with enough water to make a paste. Apply this mixture to the joint, bolt firmly together and in twelve hours it will set.

Permanent Cement for Steam Pipes: To make a permanent cement used for stopping leaks in steam pipes where calking or plugging is impossible, mix black oxide of manganese and raw linseed oil, using enough oil with the manganese to bring it to a thick paste; apply to the pipe or joint at leak. It is best to remove pressure from the pipe and keep it sufficiently warm to absorb the oil from the manganese. In twenty-four hours the cement will be very hard.

High-pressure Water Pipes: A highly recommended packing and cement, combined, for making tight joints in high-pressure water pipes, is made as follows: Mix with boiled linseed oil, to the consistency of putty, these ingredients: Ground litharge, 10 pounds; plaster-of-paris, 4 pounds; yellow ochre, ½ pound; red lead, 2 pounds; cut hemp fiber, ½ ounce. The hemp fiber should be cut in lengths of about ½ inch, and thoroughly mixed into the putty material. Its office is to give consistency to the cement. The cement is applied to the joint similarly to any other cement. It dries thoroughly in from 10 to 12 hours.

Cement to Resist Acids: A cement that withstands hydrochloric acid vapors consists of resin, 1 part; sulphur, 1 part; fireclay, 2 parts. A cement compound of boiled linseed oil and fireclay acts well with most acid vapors. A composition of glycerin and litharge is useful in this connection, especially when made up according to the following formula: Litharge, 80 pounds; red lead, 8 pounds; "flock" asbestos, 10 pounds. It should be fed into a mixer, a little at a time, with small quantities of boiled oil (about six quarts of oil being used). Sockets in 3-inch pipes carrying nitric acid, calked with this preparation, showed no leaks in nine months.

Packing to Resist Gasoline Vapor: To prepare packing for joints in pipes, etc., carrying gasoline vapor, mix a quantity of graphite and kerosene to a thick paste and apply the paste to both sides of sheet asbestos. When dry, the packing may be cut to the shape desired. The graphite helps the asbestos to make intimate contact with the iron and thus maintain a tight joint continuously at high temperature for an indefinite time.

Center Indicator. The center test indicator is used for setting a center-punch mark (the position of which corresponds with the center or axis of the hole to be bored) in alignment with the axis of a lathe spindle.

Centering Machines. Many shops have a special machine for forming centers in the ends of parts preparatory to turning the parts in a lathe. One type of centering machine is equipped with two centering heads so that both ends may be centered without reversing the position of the work.

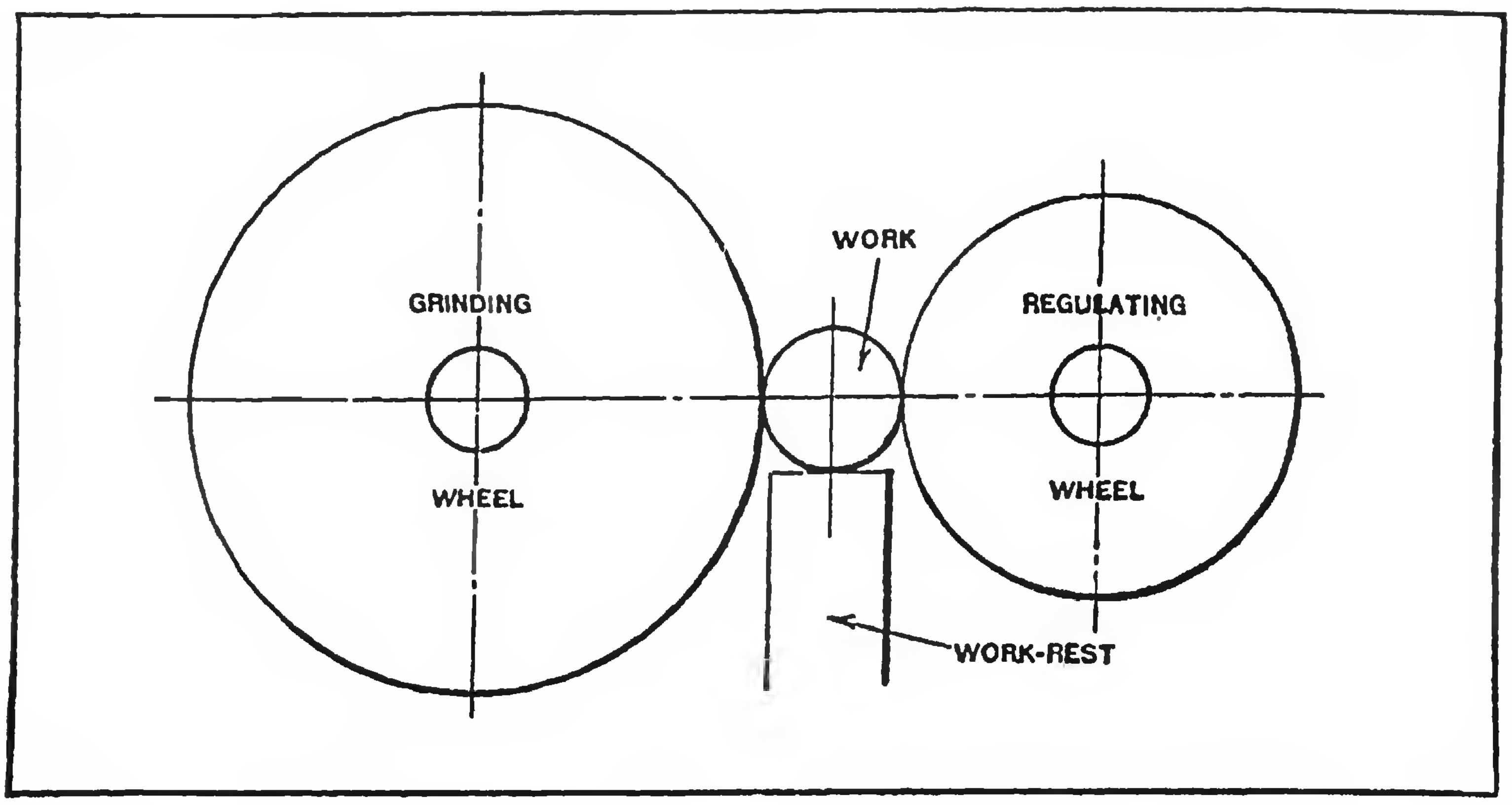
Centering Mechanisms. Centering mechanisms, in machine design, are devices used for automatically returning a machine member to the starting point or central position.

Centerless Grinding. Centerless grinding is the grinding of cylindrical work without supporting it on centers in the usual way. The principle of centerless grinding is illustrated by the diagram. Two abrasive wheels are mounted so that their peripheries face each other, one of the wheels having its axis so arranged that it can be swung out of parallel with the axis of the other wheel by varying amounts, as required. Between these two abrasive wheels is a work-supporting member equipped with suitable guides. The grinding wheel forces the work downward against the work-rest and also against the regulating wheel. The latter imparts a uniform rotation to the work which has the same peripheral speed as the regulating wheel, the speed of which is adjustable.

Through-feed Grinding: There are three general methods of centerless grinding which may be described as through-feed, in-feed, and end-feed methods. The through-feed method is applied to straight cylindrical parts. The work is given an axial movement by the regulating wheel and passes between the grinding and regulating wheels from one side to the other. The rate of feed depends upon the diameter and speed of the regulating wheel and its inclination which is adjustable. It may be necessary to pass the work between the wheels more than once, the number of passes depending upon such factors as the amount of stock to be removed, the roundness and straightness of the unground work, and the limits of accuracy required.

In-feed Grinding: When parts have shoulders, heads or some part larger than the ground diameter, the in-feed method usually is employed. This method is similar to the "plunge cut" form grinding on a center type of grinder. The length of the section or sections to be ground in any one operation is limited by the width of the wheel. As there is no axial feeding movement, the regulating wheel is set with its axis approximately parallel to that of the grinding wheel, there being a slight inclination to keep the work tight against the end stop.

End-feed Grinding: The end-feed method is applied only to taper work. The grinding wheel, regulating wheel, and the blade or work-rest are set in a fixed relation to each other and the work is fed in from the front mechanically or manually to a fixed end



Principle of the Centerless Grinding Process

stop. Either the grinding or regulating wheel, or both are dressed to the proper taper.

Automatic Centerless Grinding: The grinding of relatively small parts may be done automatically by equipping the machine with a magazine, gravity chute, or hopper feed, provided the shape of the part will permit using these feeding mechanisms.

Rates of Production: Rates of production vary widely according to the character of the work, the material, the accuracy and finish required, and other factors. For example, production often varies from two or three hundred up to several thousand pieces per hour. As a general rule, parts ground by the through-feed method require two passes and from 0.010 to 0.015 inch of stock is removed; however, when an extra-fine finish and extreme accuracy are essential, as for piston-pins, etc., the number of passes is increased. Most work is ground either by the through-feed or in-feed methods. The rate of production with the through-feed method depends chiefly upon the amount of stock to be removed, whereas, with the in-feed method, the production rate is limited to a considerable extent by the time required for loading and unloading.

Centerless Grinding, Internal: Internal grinding machines based upon the centerless principle utilize the outside diameter of the work as a guide for grinding the bore which is concentric with the outer surface. In addition to straight and tapered bores, interrupted and "blind" holes can be ground by the centerless method. When two or more grinding operations must be performed on the same part, such as roughing and finishing, the work can be rechucked in the same location as often as required.

Center of Buoyancy. The center of gravity of the liquid displaced by a body immersed in it. See Buoyancy.

Center of Gravity. Under the influence of gravity, all bodies tend to move toward the earth's center. Gravity acts at every point of a body. All bodies are composed of particles, each of which has weight, and, consequently, each is attracted by gravity. A body, therefore, is really drawn downward by a large number of forces of gravity—as many as there are molecules in the body. Gravity acts in the direction of lines converging or meeting at the center of the earth, a point so far distant, compared with the dimensions of any bodies that are likely to be considered, that these lines of action are always assumed to be parallel. It is always assumed, however, that gravity acts as a *single force* at a point called the *center of gravity.* Into whatever position a body may be placed, there is always one invariable point through which the resultant of the attracting forces always passes. This point is the center of gravity. It is a point at which, if a single force of gravity were to act in place of all the other forces, and equal in intensity to their sum, the effect upon the body would be the same as before.

Center of Oscillation. If a body oscillates about a horizontal axis which does not pass through its center of gravity, there will be a point on the line drawn from the center of gravity perpendicular to the axis, the motion of which will be the same as if the whole mass were concentrated at that point. This point is called the *center of oscillation.* The distance between the center of oscillation and the point of suspension is called the *radius of oscillation.*

Center of Percussion. If a body oscillates about an axis, then the point at which, if a blow is struck by the body, the percussive action is the same as if the whole mass of the body were concentrated at that point, is called the *center of percussion.* This point is located at the same point as the center of oscillation.

Center Reamers. A "center reamer" is a reamer the teeth of which meet in a point. By their use small conical holes may be reamed in the ends of parts to be machined as on lathe centers. When large holes—usually cored—must be center-reamed, a large reamer is ordinarily used in which the teeth do not meet in a point, the reamer forming the frustum of a cone. Center reamers for such work are called "bull" or "pipe" center reamers.

Center, Machine Tool. The centers of a machine tool, such as a lathe or grinding machine, are the conical points between which the part to be turned or ground is held. The work revolves upon the stationary or *dead center* of the tailstock and revolves with the *live center* in the headstock spindle. Experiments have shown that on lathe work at both high and low speeds the life of high-speed steel centers is easily ten times that of carbon-steel centers. In cases where the work is long and of fairly small diameter, when carbon centers are likely to burn off due to the expansion of the work being machined, the danger of spoiled centers and spoiled work seems to be entirely overcome by the use of high-speed steel centers. In grinding machines, high-speed steel centers also seem to stand the wear of the abrasive which gets into the cutting compound and which deteriorates the carbon-steel centers very rapidly. By using a chrome-nickel steel shank and a high-speed steel point a satisfactory center can be made at a much lower cost than one made entirely of high-speed steel.

Angle of Lathe Centers: In the United States the standard included angle for the work-supporting ends of lathe centers is 60 degrees. This angle is increased to 75 degrees for some axle turning or other heavy-duty lathes. British standard lathe centers have an angle of either 60 or 75 degrees as specified by the purchaser. For lathes engaged in turning axles for railway rolling stock, the angle of 75 degrees has been adopted by the British Railway Companies.

Centigrade Thermometer. This thermometer, also known as the Celsius, was originated by the Swedish astronomer Celsius, who, in 1742, described a thermometer provided with 100 graduations between the freezing and boiling point of water. On the Centigrade thermometer scale, the zero point is placed at the freezing point of water, and the graduation "100" coincides with the boiling point of water; hence, the zero on the Centrigrade scale corresponds to the 32-degree graduation on the ordinary Fahrenheit thermometer, and the 100-degree graduation on the Centigrade scale corresponds to the 212-degree graduation on the Fahrenheit scale.

$$\text{Degrees Fahrenheit} = \frac{9 \times \text{degrees C.}}{5} + 32$$

Centimeter-Gram-Second Measurement System. See Absolute System of Measurement.

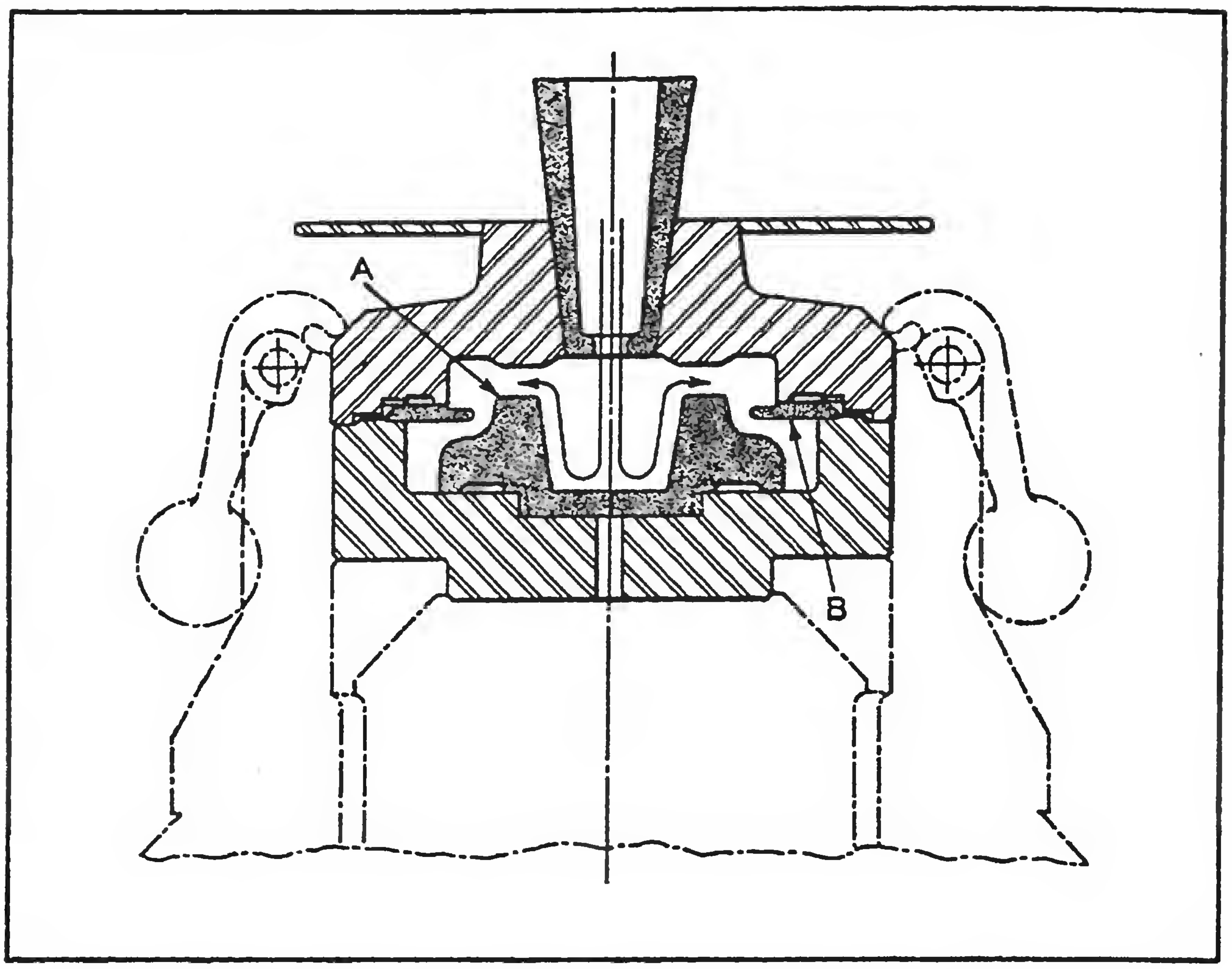
Centimeter-Gram-Second Measurement System. See Absolute System of Measurement.

Centrifugal Blower. A blower operating on the same principle as the ordinary ventilating fan, but designed for maintaining pressures from 3 to 4 pounds per square inch and used for cupola furnaces and similar requirements.

Centrifugal Casting. The centrifugal casting of metals is an old art, but it did not assume commercial importance until recent years. This process has already become an important factor in such work as the manufacture of paper-mill rolls, railroad car wheels, and cast-iron pipe. The centrifugal casting process has been successfully applied in the production of non-metallic tubes, such as concrete pipe, in the production of solid castings by locating the molds around the rim of a spinning wheel, and also to a limited extent in the production of solid ingots by a largely similar process. The usual way of casting hollow objects such as cast-iron pipe, is by introducing molten metal into a spinning mold. Where the chilling of the metal is extremely rapid, as, for example, in casting cast-iron pipe against a water-cooled chilled mold, it is imperative to use a movable spout, the latter sliding at a certain predetermined rate so that by the time the nozzle discharging the metal comes out of the mold the entire pipe is completed. The particular feature that determines the field of application of hot-mold centrifugal casting is the ability to produce long cast shapes of comparatively thin metal.

Centrifugal Casting of Gear Blanks. The accompanying diagrams illustrate how centrifugal casting is applied at the Ford plant in producing steel castings for different types and sizes of transmission gears. The molten metal is transferred by ladles suspended from monorails to the pouring stations of four large turntables equipped with steel dies or molds. Eighteen molds are mounted around each turntable. The rims of the blanks on which gear teeth are later to be cut, are cast directly against the steel walls of the molds, which gives a refining effect. Each mold is made with a cope and a drag. As each mold approaches the pouring station, with the continued rotation of the turntable, a motor drive beneath the mold is automatically started to revolve it during pouring and cooling. The speed of rotation varies somewhat with the diameter of the gear, a speed of 350 R.P.M. being employed in the case of 7½-inch diameter tractor gears. While the molds pass through the pouring and cooling stations, they are guarded on the sides and on top by sheet-metal covers. The pouring temperature of the molten metal is between 3850 and 2900 degrees F.

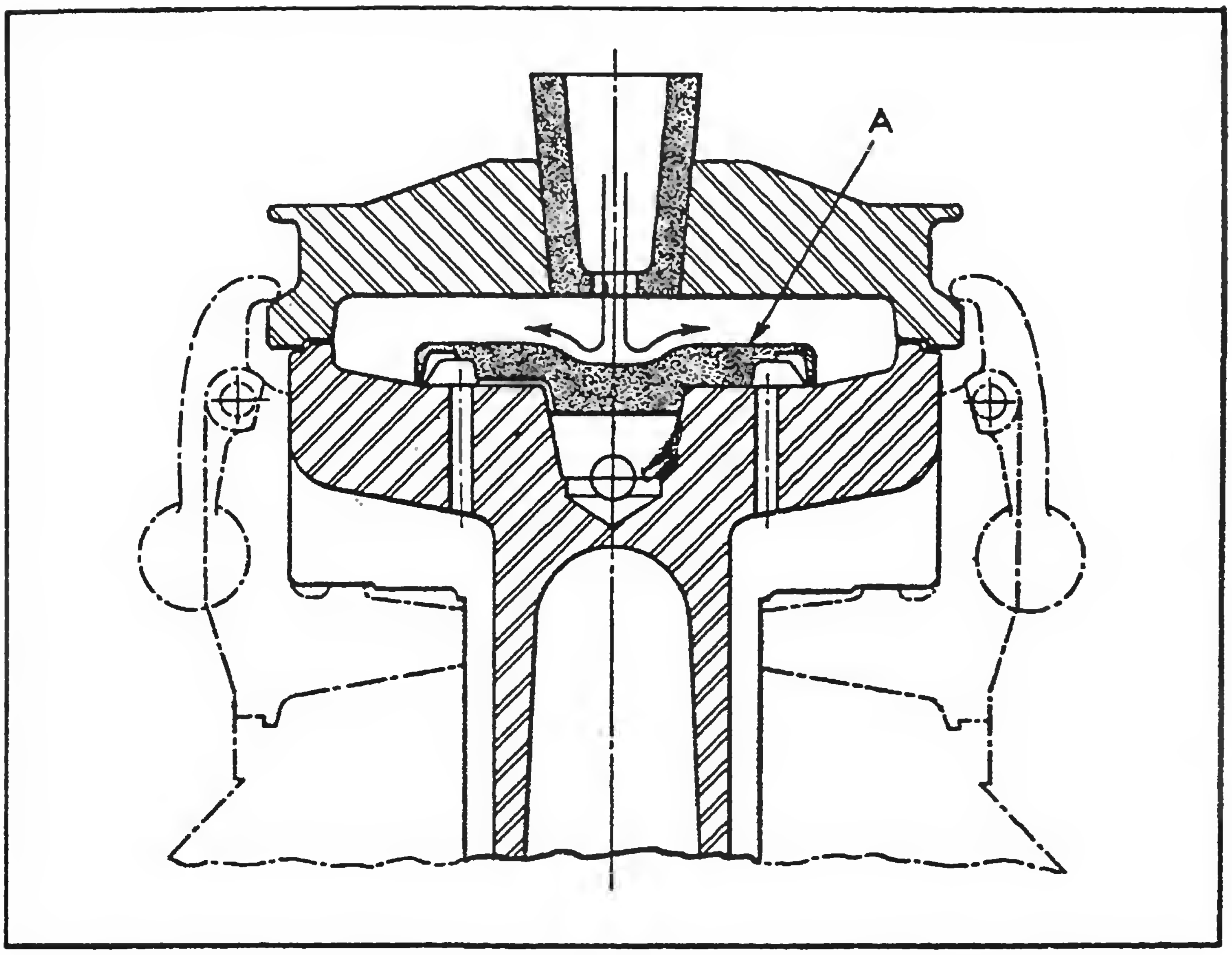
After spinning around for two minutes, the molds reach the unloading station. Here the rotation of the mold is automatically



Typical Mold Used in Centrifugal Casting of Gears, which Shows Arrangement of Cores for Recesses in the Gear Blanks

stopped to enable the casting to be removed and new cores to be inserted. At the same time, a cam mechanism beneath the turntable causes three vertical rods to rise beneath the bottom plate of the mold, so that the casting and cores are lifted with respect to the outer mold walls, and the casting is thus stripped from the mold. The cam holds the mold in the raised position until new cores have been inserted; the mold then drops back to the pouring position just before the mold drive is engaged.

The construction of two typical molds is shown by the diagrams. From the position of cores *A* and *B*, it will be seen that recesses and contours can readily be obtained on the sides or backs of gears for lightness or engineering design that would necessarily have to be machined on practically solid forged blanks. This feature of the centrifugal casting process provides substantial economies from the standpoint of scrap material and machining costs. Proper venting of the molds, which is done underneath, is of utmost importance in obtaining castings that are free of imperfections. Each revolution of the turntable and, therefore, the casting of eighteen gears takes place in four minutes. This means a possible production of 270 gears an hour from each of the four turntables. The use of steel molds enables dimensional limits on the gear blanks to be main-



Cross-sectional Drawing of a Mold Used in Centrifugally Casting Differential Ring Gears for Tractors

tained easily. From 1/32 to 1/16 inch of stock is generally allowed for the machining of these blanks. The dies and molds used in the centrifugal casting process are made from three different steels. Steels with a low percentage of carbon and with both chromium and molybdenum, or with either chromium or molybdenum, have been found satisfactory.

From the casting turntables, the gear blanks are placed on conveyors which carry them directly to an annealing furnace. After annealing, the blanks are shot-blasted and then sent to the machining department.

Compositions of Cast Gears: Truck ring gears, which are later carburized, are made from a steel of the following analysis: Carbon, 0.18 to 0.25 per cent; copper, 0.50 to 1.50 per cent; silicon, 0.20 to 0.40 per cent; manganese, 0.40 to 0.60 per cent; molybdenum, 0.25 to 0.35 per cent; chromium, 0.10 per cent maximum; phosphorus, 0.05 per cent maximum; sulphur, 0.05 per cent maximum; and nickel, from 1.65 to 2 per cent. After carburization, these truck gears are direct-quenched or reheated and oil-quenched, and then drawn to a hardness of between 58 and 62 Rockwell C.

Transmission countershaft gears and differential ring gears for passenger cars are cast from a steel of the following analysis:

Carbon, 0.30 to 0.38 per cent; copper, 0.50 to 1.50 per cent; silicon, 0.20 to 0.40 per cent; manganese, 0.55 to 0.75 per cent; molybdenum, 0.10 to 0.20 per cent; chromium, 0.80 to 1 per cent; phosphorus, 0.05 per cent maximum; and sulphur, 0.05 per cent maximum. These gears are normalized to from 170 to 196 Brinell, and, after machining, are hardened and tempered to about 477 Brinell.

Transmission gears for tractors and trucks are cast from an analysis similar to that just given, except that the carbon content is between 0.38 and 0.45 per cent. These gears are normalized to the same Brinell reading as the passenger car gears, and, after machining, are hardened to a similar degree.

Physical Properties: The physical properties of the passenger-car gears mentioned and the tractor and truck transmission gears, after being hardened by heating to 1500 degrees F. and quenched in oil, and then tempered by reheating to 355 degrees F., are as follows: Elastic limit, 212,000 pounds per square inch; tensile strength, 218,000 pounds per square inch; elongation in 2 inches, 0.75 per cent; reduction in area, 3 per cent; and Brinell hardness, 477.

Centrifugal Compressor. A blower used for pressures from 6 to 120 pounds per square inch or more; same as *turbo compressor.*

Centrifugal Dryers. See Dryers, Centrifugal.

Centrifugal Feed-Pumps. The centrifugal boiler feed-pump has many characteristics which are superior to the well-known plunger pump although the plunger pump may be preferable, providing it is large enough to run at slow speed. A plunger pump should preferably not be operated faster than 30 strokes a minute, nor with a piston speed of over 60 feet a minute. Some of the advantages of the centrifugal boiler feed-pump are as follows: Steady pressure on entire feed system; no regulators necessary, because pressure seldom increases over 15 or 20 per cent at no output; lower maintenance cost; less floor space; and lower steam consumption. One disadvantage is the possibility of excessive heating of the pump casing when operated at full speed and practically no output. Some operators prefer pump governors, but because of the long periods of inactivity the ordinary pump governor frequently does not work when required. The high suction head needed when pumping warm water and the possibility of reduced output, due to erosion of the wearing rings, are other disadvantages.

Centrifugal Force. If a body, as, for example, a weight fastened to a string, is revolved in a curved path, a pull is exerted on the string, which increases with the velocity with which the

body is revolved. According to the laws of motion, a body tends to move in a straight line unless it is acted upon by some external force which causes it to change its direction; hence, a body revolving as mentioned would tend to move in a line tangential to the circle in which it revolves, if it were not restrained from doing so by the string. The force exerted by the body upon the string or cord which restrains it is called the *centrifugal force.* Whenever any body revolves about a center it exerts a centrifugal force upon the arm or cord which restrains it from moving in a straight (tangential) line. The centrifugal force increases rapidly with the velocity, the increase being in proportion to the square of the velocity, so that, if the velocity is doubled, the centrifugal force becomes four times as great; if the velocity is made three times as great, the centrifugal force becomes nine times as great, etc. The centrifugal force also increases directly with the weight of the revolving body, but decreases with an increasing radius.

Centrifugal Pumps. A centrifugal pump in its simplest form consists of an outer casing in which inlet and outlet passages are formed and which encloses a revolving impeller, rotor, fan, bucket or runner, various names being applied to this part. The impeller has blades which are usually curved backward with reference to the direction of rotation. When the pump is in operation, the water is drawn in through the center or "eye" of the impeller, and as the water is whirled around by the blades, it is thrown outward as the result of centrifugal force and passes through the discharge outlet. The early designs of centrifugal pumps were only adapted to low pressures, and were used for forcing large quantities of water to small heights, in connection with the drainage and irrigation of land, emptying locks, and similar classes of work for which a reciprocating piston pump of sufficient capacity would have been too large and expensive. The modern centrifugal pump has been developed until the various types and designs now available are adapted to various classes of service and for high heads or pressures.

Advantages of Centrifugal Type: The principal advantages of centrifugal pumps, as compared with the reciprocating type, are greater compactness, lower initial cost, adaptability to a greater variety of conditions, little attention while operating, simplicity of construction, and reliability. The centrifugal pump has another decided advantage in that it can be directly connected to a steam or gas engine, steam turbine, or electric motor. These pumps deliver water continuously, so that shocks in the pipe lines are avoided, and they operate with little or no vibration, which makes it unnecessary to install a heavy foundation. If

the impeller blades are carefully designed, it is possible to close a valve at the end of the discharge line without an increase in pressure, so that the pump is capable of operating under practically all conditions, without danger of breakage.

Classes of Centrifugal Pumps: There are two principal classes of centrifugal pumps, namely, the *single-stage* pump and the *multi-stage pump*. The single-stage type of pump has a single impeller. The head of water which single-stage pumps of commercial design are capable of developing does not vary widely from the result obtained by the formula:

$$\text{Head} = \frac{V^2}{2g},$$

in which V = peripheral velocity of the impeller in feet per second; and g = acceleration of gravity, or 32.16 feet per second.

By arranging a number of centrifugal pumps in series so that the discharge of one is led to the suction of the succeeding pump, the head developed may be multiplied to any desired extent. Some of the early designs of multi-stage pumps were practically a series of single-stage pumps arranged in series, with but little modification of the construction. The modern designs, instead of having individual housings or casings for each pump, are equipped with one common housing with passages so arranged that the water flows from the discharge of one pump to the inlet of the next pump, through channels or passageways designed to reduce the losses through friction and eddy-currents as much as possible.

Ceralumin. An alloy of low specific gravity and comparatively high strength. Chilled castings, heat-treated, have a tensile strength of from 46,000 to 54,000 pounds per square inch; sand castings, heat-treated, from 38,000 to 40,000 pounds per square inch. Brinell hardness, 130 to 140. For use wherever light-weight, high-strength castings with high fatigue value are of importance.

Ceramic Cutting Tools. In addition to its being used as an abrasive in grinding wheels the ceramic, aluminum oxide, exhibits a combination of properties which makes it especially suited for use in the form of single-point ceramic cutting tools. These properties are its hardness, high melting point, strength, chemical stability, and thermal conductivity. These single-point tools are suitable for cutting cast iron, bronze, plastics, graphite, copper alloys, and green ceramics—materials that involve low cutting stresses but which may have a definite abrasive character.

With respect to steels, the practical use of ceramic tools has been restricted to the following categories:

1. Carbon and low-alloy steels with hardness up to 35 Rockwell C. These steels are machined with ceramics at speeds above the conventional tool-speed range, resulting in increased productivity. Certain applications have shown better tool life within the conventional tool-speed range.

2. Tool steels with hardness up to 65 Rockwell C. These steels can be machined with economical tool life, whereas conventional tools have difficulty with hardnesses in excess of 35 Rockwell C. An excellent surface finish is produced on these hard materials, one which is sometimes comparable with ground surfaces. Size can be held within normal turning tolerances for much softer materials.

3. High-strength alloy steel (such as SAE 4340 heat-treated to above 200,000-psi tensile strength). This type of steel is machined with selected ceramics at above the conventional tool-speed range with increased productivity.

4. Cast iron and cast semisteel. Both of these materials are cut at conventional tool speeds with superior tool life, and exhibit satisfactory tool life in higher speed ranges. Scalping, roughing, and finishing cuts can be accomplished equally well at high production rates with economical tool life when machining carbon, low-alloy, and high-strength alloy steels with proper selection of tools, holding fixtures, tool geometry, and lathe rigidity.

Certain materials cannot be successfully machined with ceramic tools. These include some stainless steels, high-temperature alloys, and titanium.

It is interesting to note that while stainless steel is not satisfactorily machined in the annealed condition by ceramic tools, it has been successfully handled by ceramic tools with normal procedures when heat-treated to a tensile strength of 160,000 psi or above.

Ceramics. Ceramics are nonmetallic inorganic materials, usually oxides, but also carbides, nitrides and borides, or combinations thereof, which may be processed into useful products by the application of heat. Included in this category are glass, clay products, porcelains, cements, refractories, and abrasives, some of which (aluminum oxide and silicon carbide, to mention only two) are useful in the grinding and cutting of metals.

Cerium. Cerium is one of the metallic chemical elements; its chemical symbol is Ce, and its atomic weight, 140.25. The metal has some similarity to iron in its appearance. The industrial importance of cerium is due to the use of its dioxide in the making of incandescent gas mantels. This dioxide is a white or pale yellow compound which, when heated to a high temperature, will give out a white brilliant light.

Cermet. A cermet, as the name amplies, is a combination of a ceramic and a metal. Metals may contain small amounts of non-metallic constituents, and ceramics may contain some metals, but a cermet is a material which contains both a ceramic phase and a metallic phase in substantial quantity. Titanium- or tungsten-carbide bonded with cobalt- and chromium-alumina are typical cermets.

The ceramic and metallic components of a cermet are originally in the form of powders which are thoroughly mixed, compacted, and sintered to form the cermet. Cermets may be considered to fall into one of five categories depending on their later application: (1) having high corrosion resistance, (2) having high strength and also high heat resistance, (3) having high strength and high wear resistance, (4) having properties suitable for nuclear engineering purposes, and (5) having special electrical properties.

Cermets have been used to make cutting and drilling tools and nuclear reactor fuel elements.

Cerrobend. An alloy composed of bismuth, lead, tin, and cadmium, having a melting point of 160 degrees F. It is used as a filler material in tube-bending operations to prevent flattening at the bent sections. With this material as a filler, tubes having walls as thin as 0.007 inch have been bent to small radii.

Chain. A surveyor's length measure; 1 chain = 4 rods = 22 yards = 66 feet = 100 links = 20.117 meters.

Chain Annealing. The annealing of chains before they are first used is good practice, as in that way any internal stresses that may have been set up in the process of manufacture are thereby relieved. Annealing a fatigued or crystallized chain may improve its ductility without restoring its original physical properties. In every case, however, the annealing should be carefully performed under proper conditions as to determination and control of the temperature, and with a full knowledge of the chemical composition of the material under treatment.

Chain, Engineer's. See Engineer's Chain.

Chain-Hardening Furnace. A special furnace in which the chain to be heat-treated passes over two sprockets, one at the entering and one at the leaving end of the furnace. After the chain has passed through the heating chamber, it enters directly into a cooling bath (without passing through the outer air) and then passes over the leaving sprocket and is wound upon a reel.

Chain-Making Machine. A machine employed for the making of chain of either the weldless or welded type. Some of these

machines are merely wire- or rod-bending machines that bend the links to the required size, while others, generally of the electric type, include an arrangement for welding.

Chain Materials. The best material for crane and hoisting chains is a good grade of wrought iron, in which the percentage of phosphorus, sulphur, silicon, and other impurities is comparatively low. The tensile strength of the best grades of wrought iron does not exced 46,000 pounds per square inch, whereas mild steel with about 0.15 per cent carbon has a tensile strength nearly double this amount. The ductility and toughness of wrought iron, however, is greater than that of ordinary commercial steel, and for this reason it is preferable for chains subjected to heavy intermittent strains, because wrought iron will always give warning by bending or stretching, before breaking. Another important reason for using wrought iron in preference to steel is that a perfect weld can be effected more easily.

Heavy welded chains of either mild steel or wrought iron have been supplanted in many cases by cast-steel chain. Mild-steel chain has been found to be either too ductile to retain its form under severe stress or too hard to insure reliable welds when the links have been welded together. Cast-steel chains are made successfully and practically either by casting the whole chain integral or by pouring the metal into separate link molds and then setting these links in alternate molds and pouring the intervening links around those first cast. Chains of almost any size can be, and have been, successfully cast, either integral or by alternate molds. The steel used is a special alloy electric steel; it is stated that electric steel is the only grade of steel that can be used successfully and even this steel must be specially heat-treated. The steel casting chains are very strong and of excellent durability. It is essential that steel casting chains be carefully annealed.

Chain Nomenclature, Roller. See Roller Chain Nomenclature.

Chain Oiling. A method used for lubricating horizontal journals running at high speed, in which an endless loop of chain, resting on and moving with the shaft, dips into an oil reservoir at the lower side and brings up the oil to the top surface of the journal, from where it flows over into the oil grooves.

Chain Slings. See Slings.

Chain Speeds, Roller. See Roller Chain Speeds.

Chain Sprocket Design. See Sprocket.

Chain Strength. The ultimate, or breaking, strength of a chain is usually between 1.5 and 1.7 (average 1.66) times the

ultimate strength of the straight bar or stock from which it is formed, instead of twice that amount, as might at first thought be expected because of the doubling of the bar in forming the link. The link of a chain under load is not in the simple physical condition of a bar under direct tension in a testing machine. A link is subjected to a direct tension, due to the load or pull, and to a bending moment that induces tension on the outer fibers and compression on the inner fibers of that part of the link subject to bending. The stress in tension due to bending may equal more than three (for stud links) or four (for open links) times that produced by the direct pull evenly distributed over the cross-sectional area of the bars.

Another empirical formula that is commonly used for calculating the breaking load, in pounds, of wrought-iron crane chains is: $W = 54{,}000\ D^2$, in which W = breaking load in pounds and D = diameter of bar (in inches) from which links are made. The working load for chains should not exceed one-third the value of W, and, in many cases, it should be less. When a chain is to be wound around parts such as castings, and severe bending stresses are to be introduced, a greater factor of safety should be used.

Safe Working Loads: An investigation of these matters conducted at the Engineering Experiment Station of the University of Illinois, with a critical analysis of the results attained, affords a simple and convenient formula for ascertaining the actual maximum stresses in chains and links under specified loads due to combined pull and bending, and thus furnishes a reliable means of computing safe working loads for chains. This formula, for chains with open links of the usual form, is as follows:

$$F = 2.5 \times \frac{P}{D^2}.$$

For chains with stud links,

$$F = 2 \times \frac{P}{D^2}.$$

In these formulas, F = extreme fiber stress in tension, in pounds per square inch; D = diameter of stock, in inches; P = chain load, in pounds.

In computing the safe loads for open-link chains a value of 12,000 pounds per square inch for the allowable maximum fiber stress, and an elastic limit of 24,000 pounds per square inch may be used, thus assuring in every case an actual safety factor of at least 2, based on the elastic limit of wrought iron, or more if open-hearth, low-carbon steel is used.

Chains, Studded. Tests have demonstated that the ultimate breaking strength of a chain with studded links is less than that

of an unstudded chain. This is probably due to the fact that the open links of an unstudded chain collapse until the sides are approximately parallel, so that the stresses are lower than in the studded links, the sides of which are prevented from collapsing by the studs. The principal function of the stud is to prevent the chain from kinking and catching, so that it will run free from chain lockers, etc. The stud also prevents the chain from becoming rigid under heavy strains.

Chain Transmission. This term relates to the use of chains and sprockets for transmitting power. This system of power transmission provides a positive speed ratio between the driving and driven shafts, and it is especially adapted where the center distances between the shafts are too long for gearing and too short for belting. Chain drives are compact, and as there is no initial tension on the chain, journal friction is minimized. See Silent Chain Transmission; Roller Chain; Sprocket.

Change-Gears. The gears used on screw-cutting lathes for connecting the lathe spindle stud and the lead-screw are commonly known as *change-gears*. Prior to the introduction of the quick change-gear mechanism on lathes, an assortment of these gears was provided with every screw-cutting lathe, different sizes being employed for cutting threads of various pitches; hence, the name "change-gears." The gears of a milling machine, used to drive a dividing or index head from the table feed screw for such work as cutting spirals or helices, are also known as change-gears, and this term is applied to various other changeable gearing.

Quick Change-Gear Mechanisms: On many modern lathes, the changes of feed for turning and screw cutting are obtained by means of a system of gearing which enables the changes to be made rapidly, by simply shifting one or more levers. A table or index plate attached to the machine, shows what feed rates and pitches will be obtained for different positions of the levers. Quick change-gear mechanisms are also applied to various other types of machine tools.

Change-Gears for Thread Cutting. The change-gears for cutting threads of various pitches with an engine lathe, are usually shown by a table or index plate attached to the lathe, but the proper gears to be used can be calculated by the following rule.

Rule: First find the number of threads per inch that is cut when gears of the same size are placed on the lead-screw and spindle stud, either by trial or by referring to the index plate. Then place this number as the numerator of a fraction, and the number of threads per inch to be cut, as the denominator; multi-

ply both the numerator and denominator by some trial number, until numbers are obtained which correspond to numbers of teeth in gears that are available. The product of the trial number and the numerator (or "lathe screw constant") represents the gear for the spindle stud, and the product of the trial number and the denominator, the gear for the lead-screw.

Channel. The name applied to a standard structural steel shape consisting of a web and two flanges projecting at right angles to the web and on the same side, thus forming a channel or U-shaped section. See Structural Shapes.

Channeling. The formation of irregular sections of sheet metal of indefinite length for use in the manufacture of metal furniture, automobile rims, shows cases, etc., in the small sizes, and for structural steel work, gutters, molds for cement forms, steel car manufacture, and kindred uses, in the larger sizes, by means of rolling, is known as channeling. Sheet stock of any metal may be formed cold by channeling, and any thickness up to ¼ inch may be worked without difficulty. The speed at which this class of work is handled varies from 50 to 90 feet per minute, according to the metal and the shape to be produced.

Chaplets. When the cores of foundry molds are not supported or held securely by suitable core-prints, and are likely to be moved from their proper position by the wash and lifting action of the molten metal, it becomes necessary to secure or anchor them with chaplets. These are made in a variety of shapes and sizes to meet the different conditions that may arise.

Chapmanizing. The process known as "Chapmanizing," is adapted particularly to the casehardening of the low-carbon and cheaper grades of steel, thereby eliminating, in many instances, the necessity for using expensive steels and elaborate heat-treatments. This process was developed by the Chapman Valve Mfg. Co., Indian Orchard, Mass. By applying this process to low-carbon steel, an almost glass-hard surface is obtained. This hardness penetrates to a reasonable depth, so that the surface is extremely hard even after grinding. The degree of hardness and the depth of the case can be regulated to suit the requirements of each job.

Charcoal. Charcoal is the residue consisting of impure carbon which is obtained by expelling the volatile matter from animal or vegetable substances. The most abundant source of charcoal is wood. Under average conditions, 100 parts of wood yield about 60 parts, by volume, or 25 parts, by weight, of charcoal. The modern methods of producing charcoal from wood consist in using a cast-iron retort in which the wood is heated in order to remove the volatile constituents. Valuable by-products

are also obtained in this manner (wood alcohol, wood tar, etc.). The uses of charcoal in the industries are many. It is an important fuel, especially in many metallurgical processes; it is also important as a constituent of gun powder; it is used as a filtering medium; and it has the power of removing coloring matters from solutions, and is, therefore, used to some extent in laboratory practice. The specific gravity of wood charcoal is 0.4. Its density is 25 pounds per cubic foot.

Charles' Law. The volume of a perfect gas at constant pressure is proportional to its absolute temperature. This is known as the "law of Charles." Let V = volume of gas at 32 degrees F., and V_1, the volume of the gas at any other temperature T_1, then:

$$V_1 = V\left(1 + \frac{T_1 - 32}{491.2}\right).$$

Charpy Test. The Charpy test for hardness consists of striking specially prepared specimens of work with blows that can be figured in foot-pounds. The hardness is not measured, but instead the shock-resisting qualities of the work are determined. See Impact Tests.

Charred Bone. A material frequently used in carburizing mixtures for increasing the carbon content of the surface of low-carbon steel, so that it may be casehardened. A mixture of 35 per cent of charred bone, 30 per cent of burnt leather, and 35 per cent of wood charcoal, by weight, is frequently used. See also Carburizers.

Chasers. A chaser is a form of threading tool having a number of teeth instead of a single point like the threading tools commonly used in connection with lathe work. There are three general classes of chasers; namely, hand chasers, threading tool chasers (which are rigidly held in a tool-holder and used like an ordinary lathe threading tool), and die chasers, such as are used in thread-cutting dies.

Chaser Throat: The leading side or corner of each chaser in a die-head is usually beveled. This beveled edge is known as the "throat" of the chaser and serves to begin the cut gradually when the die is first starting a thread and also as it advances. The throat of the chaser not only inclines relative to the axis of the die (or screw being cut), but it is given clearance back of the cutting edge in a circumferential direction. In some cases, the throat angle must be abrupt in order to cut a full thread close to a shoulder. Aside from a requirement of this kind, the throat should preferably be ground so that the work of cutting a thread to the full depth is distributed over at least two or three on the leading side of the die.

Chasing Dial. The thread-chasing dial, or thread indicator, which is attached to the carriage and has a worm-wheel meshing with the lead-screw, shows when to re-engage the half-nuts of the apron with the lead-screw when cutting screw threads which are not a multiple of the number of threads per inch on the lead-screw. If the half-nuts were engaged at random for taking each successive cut the tool might not follow the original cut.

Chattering. The term "chattering," as applied by machinists, means the formation of slight ridges or nicks upon a part that is either being turned, planed, milled, or ground. Chattering may be caused by the design of the machine, the nature of the work or its proportions, the care and adjustment of the parts of the machine, the methods of setting the work in the machine or of driving it, the shape of the cutting tool or the manner in which it is set in the machine, or the speeds and feeds employed for cutting.

The action that occurs when a turning operation is accompanied by chattering is as follows: Either the tool or the work is momentarily deflected, causing slight changes in the depth of cut taken. This action occurs very rapidly as the part revolves, so that the surface, instead of being turned smooth, is covered with small ridges or corrugations. Chattering not only mars the turned surface, but quickly dulls the cutting edge of the tool. High cutting speeds tend, far more than slow speeds, toward producing minute and rapid vibrations in all parts of the machine, and, in order to prevent or absorb these vibrations, the members of the machine which support the tool and work should be massive, to secure the required rigidity. A common source of chatter can be eliminated by a systematic method of adjusting the working parts of the machine in order to eliminate unnecessary play or lost motion.

The principal cause of chatter marks on parts which are ground in cylindrical grinding machines is the vibration of the work, which may be due to a number of causes, such as a lack of proper support for the work, lack of rigidity in the machine and incorrect work speed.

Checking Engineering Drawings. After drawings have been completely finished and contain all the necessary dimensions, symbols, abbreviations, notes, etc., it is the general practice to check them. The object of checking is not only to locate any errors that may have been made in the dimensioning, but to discover defects of any kind which should be remedied. A competent checker may suggest changes in design or in the method of manufacture. The checking may be done by the chief draftsman or by one or more experienced draftsmen who have been assigned to

this work. In smaller drafting-rooms, the draftsmen often check each other's drawings, but a man should not check his own drawing, if this can be avoided, because he is not so likely to detect his own mistakes as someone else.

The tracing is generally used when checking, although some prefer a blueprint from the tracing. When using a blueprint, all corrections or changes may be indicated on the print in red pencil, and all figures that are correct may be checked with, say, a yellow pencil. After all changes have been approved, the changes indicated in red are made on the original prints which are afterward compared by the checker with the blueprint to see if all changes have been made correctly. This checked blueprint may also be filed away for reference purposes in case there is any doubt as to who is to blame. After a tracing has been checked, the initials of the man checking it and the date should be placed on a space provided. The checking of drawings should be done in a systematic way, and checking lists are often issued which show just what requires checking or, at least, the essential details of this work. These lists are prepared partly with reference to the product of the plant or the conditions peculiar to it, although many items found in checking lists apply regardless of the class of work.

Checking of Steel. The cracking or checking which sometimes occurs when grinding high-speed steel tools is said to be caused invariably by the use of cooling water while rough-grinding the tool. A practice recommended is as follows: Have the tool rough-forged to approximately the required shape; grind the tool slowly at first until it becomes warmed through, after which the grinding may be done rapidly without injury to the tool, but water should not be used when rough-grinding, as it tends to cause checking.

Checking Systems for Tools. See Tool Checking Systems.

Check-Nut. A check-nut or jam nut is used for binding or securing the ordinary nut screwed onto the end of a bolt. See Jam Nut.

"Check" Type of Gage. "Checks" are simply standards for the inspection of wear of working and inspection gages. They indicate when the gages are so worn by use that they are no longer suitable for the purpose for which they are intended. Checks may be used for a considerable number of gages, but are necessary in the case of many types, such, for example, as ring or snap gages which are too small to be measured by ordinary methods.

Check-Valves. Check-valves are designed to allow any fluid to pass through them in one direction only, any pressure in an op-

posite direction tending to immediately close the valve. Check-valves are made in several forms, including the globe check-valve. the swing check-valve and the ball check-valve. The ball type is designed particularly for use with heavy liquids, such as molasses or heavy oils. The particular advantage of the ball valve is that it opens readily and gives a free and unobstructed passage through the valve body, which is not likely to become clogged or obstructed by foreign matter. The boiler check-valve is located between the injector and the boiler, its function being to permit the passage of feed water to the boiler, without permitting any backward flow when the injector is not working. It is essential that the check-valve be tight and have the proper amount of lift.

Chemical Affinity. The force which holds together the molecules of a substance. It is also known as chemical force.

Chemical Analysis. The resolution of complex bodies into their elements is termed *chemical analysis.* When only the constituent elements of a substance are determined, the analysis is said to be *qualitative;* but when both the constituents and the percentages of each are determined, the analysis is said to be *quantitative.* When the quantitative analysis determines the percentages of the compounds of which a substance is made up, it is said to be a "proximate analysis"; when the quantitative analysis determines the percentages of the elements of a substance, it is said to be an "ultimate analysis." For example, the proximate analysis of coal, which is the one usually made, shows the percentages of volatile matter, fixed carbon, moisture, sulphur, and ash; but the ultimate analysis will show the percentages of hydrogen, oxygen, carbon, nitrogen, etc. An analysis performed with the aid of a liquid solvent or reagent is termed a "wet" or "humid" analysis. A *reagent* is any substance used to effect a chemical change in another substance for the purpose of determining its component parts, or to ascertain its percentage composition. An analysis performed with dry reagents and heat is termed a "dry" analysis. The analysis of ores is usually termed "assaying"; this is divided into "wet assaying" and "fire assaying."

Chemical Change. A change in a substance which takes place within the molecules is called a chemical change. For example, if a magnesium rod is heated, it will combine with oxygen and form a white easily powdered substance known as "magnesia" or "magnesium oxide"; the magnesium has thus undergone a chemical change.

Chemical Equations. Chemical reactions are generally stated in the form of equations. In these, the symbols and formulas of the substance and the actions that take place are shown on one side of the equals sign and the result obtained is shown on the

other. The equations show the relative number of molecules and atoms involved. They also indicate the weight of the quantities involved. As in the case of algebraic equations, the quantities on one side of a chemical equation must always equal the quantities on the other. Thus if the weight of one factor or product is known, the weights of all other factors and products may be calculated from the equation representing the reaction. As an example of a chemical equation, the following is given which indicates that calcium carbide and water forms calcium hydroxide and acetylene:

$$CaC_2 + 2H_2O = Ca(OH)_2 + C_2H_2.$$

Chemical Equivalents. Owing to the difficulty of determining atomic weights, some chemists have advocated the use of "chemical equivalents." The *equivalent* of an element is the relative weight of the element that combines with one part, by weight, of hydrogen. For example, 8 parts of oxygen, 35.4 parts of chlorine, 80 parts of bromine, and 16 parts of sulphur combine, respectively, with 1 part, by weight, of hydrogen; therefore, 8, 35.4, 80, and 16 are said to be the equivalents of these elements. However, many elements do not combine with hydrogen, and some combine with it in more than one proportion, so that the difficulty of determining the equivalent is as great as the difficulty of determining the atomic weight.

Chemical Formula. An abbreviation used to designate a chemical compound; it shows how many atoms of different chemical elements are contained in one molecule of the compound. For example, the chemical formula of ferric oxide is F_2O_3, which shows that one molecule of ferric oxide contains two atoms of iron, the symbol of which is Fe, and three atoms of oxygen, the symbol of which is O.

Chemical Milling. In chemical milling, the metal part is immersed in a tank containing a chemical solution which etches away the desired material at a controlled rate from selected areas. Areas of the workpiece which are not to be etched are protected by an inert strippable masking material such as neoprene or vinyl. This process is particularly suitable for the weight reduction of large parts where the depth of material to be removed is relatively shallow. A limitation is that the chemicals used will remove material sideways (under the masked surfaces) as well as downwards from the surface to be etched.

Chemical Reaction. Any chemical change that takes place is termed a *chemical reaction.* The change may be a rearrangement of the atoms of the different molecules, the combining of two or more molecules into one, two, or more different molecules, or the splitting up of one molecule into two or more molecules. All molecules entering into a reaction are called "factors"; those issuing from a reaction are called "products."

Chemistry. Chemistry is the science that treats of the composition of substances and the changes they undergo. Chemistry has in the past generally been divided into two classes, organic and inorganic, because of the belief that some substances could not be artificially produced; but, with modern developments in the laboratory, many of the substances classified as organic have been produced from inorganic matter. The division, however, is still maintained as a matter of convenience, and *organic chemistry* is commonly said to be the chemistry of carbon compounds, while *inorganic chemistry* is the chemistry of all other elements and compounds. This definition, however, is not absolutely true, as some carbon compounds, such as carbon monoxide, carbon dioxide, carbon disulphide, silicon carbide, and iron carbides that occur in cast iron and steel, are practically always considered as inorganic; while some substances, such as chloroform, that do not contain carbon, are treated as organic. Chemistry is also divided into *synthetic,* or the building up of more complicated from less complicated substances, and *analytic,* or the determining of the components of a substance. The term "synthetic" is also used for substances made by artificial means in the laboratory, to distinguish them from like substances obtained directly from plants or animals.

Cherrying. The term "cherrying" relates to the milling of circular or spherical impressions in dies as for example when a milling cutter is sunk to one-half its depth in milling out a circular recess. A *cherry* is a milling cutter, usually made integral with an arbor the length of which varies with the requirements of the work to be done. Many devices and attachments for both the milling machine and die-sinking machine have been devised to eliminate chipping and the difficult hand work of drop-forging dies, etc.

Chester Emery. A natural abrasive obtained from Chester, Mass., which is not considered to be of quite as high a grade as the imported Naxos and Turkish emery. It contains a large percentage of non-cutting elements; the crystalline alumina, which determines the cutting qualities, being only about 55 per cent of the total composition.

Chestnut Coal. A term indicating the grading of the coal as to size. This grade will not pass a screen of $\frac{3}{4}$-inch mesh, but will pass a screen of $1\frac{3}{8}$-inch mesh.

Cheval-Vapeur. Same as *Metric Horsepower.*

Chilled Castings. A chilled casting is one which has been cooled suddenly by casting it in contact with some material which will rapidly conduct heat away from the surface of the casting. The effect is to produce a surface of great hardness which will

withstand considerable wear. Such castings are used for many purposes, such as for railroad car wheels, rolls, jaws of crushing machines, stamps, etc. In the case of cast-iron chilled castings, the chill is always produced by iron in the mold. Either the complete mold is made of iron, or iron slabs called "chills" are imbedded in the mold, so that certain surfaces (those exposed to the greatest wear) are chilled. Thus, the tread of car wheels and the wearing surfaces of machine tool beds are often chilled to increase the life of the wheel or machine ways. A casting poured against a surface of solid iron may be chilled from 1/8 inch to 1 inch in depth. When a casting has a heavy section which adjoins a comparatively light section, chills have been used, in special cases, to secure more uniform cooling between the heavy and light sections in order to prevent the formation of internal blow-holes.

Chills for Castings: Chills may be used as part of the mold or in the same capacity as a core. The patternmaker's job is to fit the pattern to the chill as they are rammed up together; if a round hole is to be chilled, core-prints are fitted to the pattern and the chill is made with considerable taper so that it may be driven out. It is sometimes desirable to make sections of pipe to bolt together without finishing the flanges; and to do this, metal ends are used in the mold, not to chill the casting but to form a finished flange. In this case, the flanges are made long to form core-prints for the metal ends, the face sides of which are grooved with concentric V-grooves to give the packing a hold. The core is carried on an arbor that fits openings turned in the end pieces which are also drilled with holes through which the bolt hole cores are pushed.

Chimneys. The requirements of a chimney are that it shall provide sufficient draft to burn the required amount of fuel on the grate of a boiler in a given time, and also carry off the obnoxious gases. The strength of the draft depends upon the height of the chimney, while the volume of the gases to be carried off fixes the sectional area of the flue. The exact proportions depend upon the kind and amount of fuel to be burned, the design and arrangement of the boilers and connecting flues, and the altitude of the plant above the sea level. No universal formula has yet been devised which covers all of these conditions, so that it is more common in designing a chimney to use experimental data obtained from chimneys in actual use. As a rule, in ordinary boiler work the chimney lining need not be more than one-fifth of the height of the chimney, if the exhaust gases do not have a temperature over 800 degrees F. If the temperature of the exhaust gases is higher, the lining must extend higher inside the chimney.

The *draft* produced by a chimney is due to the comparatively

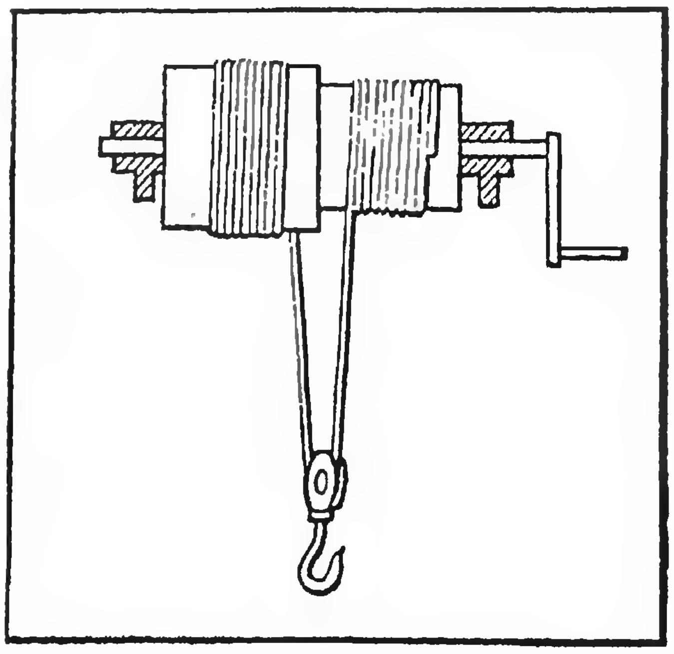
high temperature of the furnace gases which pass up the chimney. As these hot gases are lighter than an equal volume of outside air, the pressure within the chimney is less than the atmospheric pressure surrounding the chimney; consequently, air from the outside naturally flows through the furnace and into the chimney and the necessary draft is thus obtained.

China Clay. An aluminum silicate found in nature as a fine white powder. It is used in paints for the protection of iron and steel against corrosion. It grinds in 28 per cent of oil.

Chinese Alloys. There are a number of alloys known as Chinese bronze, Chinese copper, etc. These have somewhat varying compositions. Chinese bronze, according to one formula, contains 83 per cent copper, 10 per cent lead, 5 per cent tin, and 2 per cent zinc. Chinese white copper contains about 40 per cent copper, 32 per cent nickel, 25 per cent zinc, and 3 per cent tin. The metal used for Chinese gongs contains 81 per cent copper and 19 per cent tin; this is practically the same composition as that used for bell metal, which is 80 per cent copper and 20 per cent tin.

Chinese Windlass. The Chinese windlass (see diagram) is of the differential motion principle, in that the resultant motion is the difference between two original motions. The hoisting rope is arranged to unwind from one part of a drum or pulley onto another part differing somewhat in diameter. The distance that the load or hook moves for one revolution of the compound hoisting drum is equal to half the difference between the circumferences of the two drum sections.

Chip and Oil Separators. Chips from screw machines and other classes of machine tools requiring oil lubrication for the cutting tools, may contain considerable oil even after the chips have been drained by gravity. The average amount of oil on screw machine chips is about 3 gallons per 100 pounds, and by gravity draining only about 30 per cent of this oil is reclaimed; hence, oil extractors are commonly used in machine tool-using plants. These extractors operate on the centrifugal principle. The chips are placed in a perforated pan or basket which is rotated rapidly, thus causing the oil to fly out through the perforations. With these centrifugal oil extractors from 1 to 5 gallons of oil per 100 pounds of chips may be reclaimed. About 2 gallons per 100 pounds is a fair average, but the amount varies considerably, de-


Chinese Windlass

pending upon the extent of previous draining by gravity and the viscosity of the lubricant. By this centrifugal method practically all of the oil is reclaimed and the process requires only 2 or 3 minutes. Some centrifugal separators are driven by belt and others by a direct-connected electric motor, and the speeds vary from 500 or 600 R.P.M. up to about 1000 or 1200 R.P.M.

Chip and Work Separators. The machines used for separating chips from screw machine products, etc., usually are either of the blower type which utilizes a blast of air for blowing the chips from the work, or the purely mechanical type which depends entirely upon the reciprocating movement of a screen for separating the chips by a sifting process.

Chip Separators of the Blower Type: One chip and work separator of the blower or pneumatic type has a work-holding box which is placed in a vibrator. The vibrator spreads out the work and chips and the latter are blown through a hood while the finished parts drop into a pan. This type of machine is built in large and small sizes. The small separator may be used not only for screw machine products, etc., but for watch, clock and other small parts, and also for separating parts from sawdust after tumbling. Parts that are very small and light may be separated by means of an exhauster attachment. In operating this attachment, the material is placed in the work pan and pushed to the inlet opening in the elbow. The chips are then sucked up through the elbow and exhauster, and discharged through the hood; while the finished parts drop through a hole in the bench or table into a box. The lever is operated to regulate the air blast for both blowing and exhausting; the smaller the parts are, the less air is required.

Another blower type of separator operates in the following manner. The work and chips as they come from the screw machine or other machine tool, are put into a hopper at the top of the separator. This hopper is connected by a gate with an inclined slide, and both hopper and slide have a compound vibratory motion which spreads the work and chips out in a thin layer as they move down the slide after the hopper gate is opened. In this slide there is an opening through which the work drops into a tote pan. The chips, however, are prevented from falling through the opening and are floated over it by a draft of air from a centrifugal blower located beneath the hopper and slide. The machine is equipped with a hood to deliver the chips into a wheelbarrow.

Reciprocating Type of Chip Separator: One design of machine for separating chips from work, operates with a reciprocating motion derived from a crank and rod connected with a "shaker box" which contains the work and is reciprocated on the horizontal ways of the machine stand or base. The shaker box has

a wire screen bottom, the mesh of the screen depending upon the kind of chips. This machine is intended for use in combination with an oil separator for separating chips from finished work, after the oil has been separated from both work and chips.

Separating Monel and Steel Chips: A magnetic device has been used successfully by one of the large manufacturers of electrical equipment for separating iron and steel chips from monel metal chips, thus effecting a large saving annually due to the reclaiming of the monel metal. Experiments in using the magnetic method were not successful at first, because the monel metal was picked up by the magnet, but by using a rheostat on the magnetic separator and reducing the current to a minimum it was found that the iron and steel chips could be picked up and the monel chips dropped. During cold weather, congealing of the oil on the chips may interfere with clean separation because the oil holds the two metals together; however, this difficulty may be overcome by drying the chips prior to separation.

Chip Breaker. The term "chip breaker" indicates a method of grinding turning tools, that will break up the chips into short pieces, thus preventing the formation of long or continuous chips which would occupy considerable space and be difficult to handle. The chip-breaking form of cutting end is especially useful in turning with carbide-tipped steel turning tools because the cutting speeds are high and the chip formation rapid. The chip breaker consists of a shoulder back of the cutting edge. As the chip encounters this shoulder it is bent and broken repeatedly into small pieces. Some tools have attached or "mechanical" chip breakers which serve the same purpose as the shoulder.

Chip Crushing Machine. This type of machine is used for crushing metal chips and scrap so that a much larger amount may be stored or shipped in a given space; moreover, by crushing the chips a larger percentage of oil can be reclaimed. One machine on the market has a capacity of about 5 tons of steel chips per eight-hour day, and another machine has about the same tonnage capacity per hour.

Chipless Machining. Chipless machining is the term being increasingly applied to the newer methods of cold forming metals to the required finished part shape (or nearly finished shape) without the production of chips (or with a minimum of subsequent machining required). Cold forming of steel is not new—having long been performed in such operations as wire-, bar-, and tube-drawing; cold-heading; coining; and conventional stamping and drawing. However, newer methods of plastic deformation with greatly increased degrees of metal displacement have been developed. Among these processes are: the rolling of serrations, splines, and gears; power spinning; internal swaging; radial forging; the cold forming of multiple-diameter

shafts; cold extrusion; and high-energy-rate forming, which includes explosive forming. Also, the not-so-new processes of cold heading, thread rolling and rotary swaging are also considered chipless machining processes.

Chips, Briquetting Metal. See Briquetting Metal Chips.

Chisels, Metal-Cutting. See Cold Chisels.

Chlorine. Chlorine is a gaseous chemical element of greenish-yellow color. Its symbol Cl; atomic weight, 35.46; specific gravity, 2.49 (air = 1); liquefying point, —34 degrees C. (—29 degrees F.); and solidifying point, —102 degrees C. (—152 degrees F.). It is never found in nature in an uncombined condition, but is widely distributed in combination; it is one of the constituents of common salt. Combined with hydrogen, chlorine forms hydrochloric acid. Chlorine is used for many purposes in the industries, and many processes have been devised for its production.

Chlorine-Proof Cement. A luting material used in electrolytic and chemical plants, which will withstand the action of chlorine, as well as that of acids and alkalies. It consists of one part Portland cement, one part powdered glass, one part silicate of soda, and a small amount of powdered slate. Linseed oil made into a paste with fireclay will also prove impervious to chlorine for a short time.

Chromatic Speed Range. The "chromatic speed range" for speed-changing mechanisms is based on the square root of 2, or 1.4142. This range is simply a geometrical progression with a ratio of 1.4142, or a smaller ratio may be used, as 1.189, which is the square root of 1.4142, or the fourth root of 2. The logarithmic scale gives a number of values the adoption of which as standards in designing speed-changing mechanisms has been proposed. These values are approximately as follows: 4.75, 5.67, 6.75, 8, 9.5, 11.3, 13.5, 16, 19, 22.6, 26.9, 32, 38, 45.2, 53.8, 64, 76, 90, 108, 128, 152, 181, 215, 256, 304, 362, 430, 512. The ratio of the geometrical progression, in this case, is 1.189, although the increment of change might be any power of 1.189. With this speed range back-gear ratios of 2, 4, 8, and 16, according to the range desired, could be employed. This point is considered important, because, on some classes of machines, especially lathes, the back-gear ratio can be utilized conveniently for obtaining coarse leads.

Chromel. Chromel is the trade name for a high-grade alloy containing, in its best grade, 80 per cent nickel and 20 per cent chromium. Another grade contains 85 per cent nickel and 15 per cent chromium, while still a third grade contains approximately 61 per cent nickel, 25 per cent iron, 3 per cent manganese, and 11 per cent chromium. All other elements are classed as impuri-

ties and are held down to a minimum. Chromel alloys have an electrical resistance from fifty to sixty-five times greater than that of copper, depending on the grade of the alloy, and they also have a very high resistance to heat.

The behavior of this alloy under high temperatures makes it suitable for use as a heating element in all kinds of electrically heated devices, from electric toasters to furnaces used for heating steel preparatory to hardening or forging. Iron-free chromel may be found in use in the thermo-couples of nearly all pyrometers that work at a temperature up to 2200 degrees F. This alloy is said to be mainly responsible for the rapid growth of the electric heating industry in which it is used for heating apparatus that operates at temperatures between 1500 and 2200 degrees F. The third grade of the alloy, in which iron is an ingredient, is used extensively in the construction of flat-irons, ovens, and heating devices that operate below a temperature that does not exceed the oxidizing point of the alloy.

Chrome Iron. The term "chrome iron" is sometimes applied to an alloy consisting primarily of iron and chromium. Alloys of this kind and containing from 27 to 30 per cent chromium were developed originally for high-temperature installations, but they also resist corrosion, nitric acid and most organic acids. See Duraloy.

Chromium. Chromium is one of the metallic chemical elements; its chemical symbol is Cr, and its atomic weight, 52.0. The specific gravity of the pure metal is 6.9, but the commercial metal has a specific gravity of about 6.5, making its weight per cubic inch equal to 0.235 pound. The melting point of chromium is 1510 degrees C. (2750 degrees F.). Its electrical conductivity (silver = 100) is 16. Chromium is an intensely hard, brittle metal, whiter and more lustrous than iron in its appearance, but slowly oxidizing in the air. It does not occur free in nature, but is found in a number of different minerals. The mechanical importance of chromium is as an alloying metal for steel. *Chromium steels* have remarkable qualities as regards tensile strength and high elastic limit, when properly heat-treated. Chromium, when used in the manufacture of chromium steel, is introduced in the form of a chrome-iron ore, also known as *chromite* or *chromic iron.* This is the chief commercial source of chromium and its compounds.

Chromium Plating. Chromium plating is an electrolytic process of depositing chromium on metals either as a protection against corrosion or to increase the surface wearing qualities. In general, the equipment used is similar to that used for other kinds of electro-plating, but the results are more affected by the

temperature of the bath and the current density. The hardest deposit of chromium is obtained at the highest current density that can be applied without "burning." A temperature for the bath of about 45 degrees C. (113 degrees F.) and 100 amperes per square foot gives a very bright deposit. The "throwing power" of the chromium plating process is relatively poor, which means that it is comparatively difficult to deposit the chromium in recesses or on parts of irregular shape. A chromium plated surface can be polished so that it will be more brilliant than nickel and have practically the same reflecting power as a high-grade mirror. A chromium coating can be deposited up to at least 0.005 inch thick, which is thicker than ordinarily required in commercial work; brightness of surface is sacrificed with increase of thickness. Chromium plated surfaces are usually hard and resist tarnishing and corrosion.

Chromium plating can be applied to practically all commonly used metals, with the exception of silver and aluminum, and even aluminum alloy die-castings of certain compositions have been successfully plated with chromium. Only two acids, muriatic and hydrochloric, attack chromium plating and its bright lustrous finish is unaffected by heat up to temperatures of 700 degrees F. The melting point is about 3000 degrees F.

Hardness of Chromium Plate: Although it is difficult to gage accurately the hardness of chromium plating, scratch tests indicate that it has about the same hardness as the sapphire. Glass can be scratched readily with the edge of a piece of brass strip stock which has been chromium plated, whereas a similar piece which has been nickel plated will simply slide over the glass.

Chromium Plated Cutting Tools: Metal-cutting tools which have been built up on their cutting edges by chromium plating have given excellent results. A 3/16-inch reamer used for reaming holes in a monel metal part, for instance, was brought up to the required size by chromium plating. In this case 0.001 inch of metal was put on. The reamer thus treated shows no sign of wear even though it has already produced several times as much work as the best reamer previously obtainable.

Among the various types of cutting tools which have been chromium plated are taps and forming tools. Manufacturers of bakelite and other phenol products have, in some instances, found it profitable to have their cutting tools chromium plated. The hardness, resistance to corrosion and the smooth finish of chromium plating, which lessens chip clogging, makes chromium plated taps especially well adapted for use on bakelite parts. Chromium plated files have proved excellent for use on soft metals, as they do not clog or load up as quickly as unplated files and hold their edge exceptionally well. Chromium plated rivet

spinning tools have been found to stand up from ten to fifteen times longer than the hardest unplated steel tools.

Dies and Metal Spinning Tools: Dies for molding or forming bakelite products of simple form have been found to give longer service and produce a better finish when chromium plated. The depth of plating for dies of this kind is about 0.002 inch. The low coefficient of friction of chromium plated surfaces undoubtedly contributes much to the success of certain metal-cutting or metal-working tools, such as punches and dies for drawing seamless tubes and shells.

Building Up Worn Plug Gages: Plug gages which have been worn undersize can be built up by chromium plating and then lapped to size. Any amount of metal up to 0.004 or 0.005 inch can be added to a worn gage. Chromium oxide is used in lapping chromium plated gages, or other parts, to size and for polishing. When the chromium plating of a plug gage has worn undersize, it may be removed by subjecting it to the action of muriatic acid. The gage is then built up again by chromium plating and lapped to size. When removing the worn plating the gage should be watched carefully and the action of the acid stopped as soon as the plating has been removed in order to avoid the roughening effect of the acid on the steel.

Cleaning Work to be Plated: Work which is to be chromium plated must be clean and free from dirt or grease, the same as when any other finish is to be applied. Parts which have been cleaned for finishing by nickel plating are generally sufficiently well prepared for chromium plating. An effective method of cleaning greasy or dirt covered parts is to wash them in a 5 per cent sulphuric acid solution.

Chromium-Vanadium Steel. Alloy steels of this class, according to the S.A.E. specifications, contain 0.80 to 1.10 per cent chromium; 0.18 per cent vanadium preferably, and a minimum of 0.15 per cent; 0.60 to 0.90 per cent manganese in most cases; a maximum of 0.04 per cent phosphorus, and the same maximum of sulphur; and a carbon content ranging from 0.15 to 1.05 per cent, depending upon the class of steel and its application. Most chrome-vanadium steels contain from 0.20 to 0.50 per cent carbon. Many heat-treated forgings are made from these steels.

Chromizing. Chromizing is somewhat similar to the process of calorizing. It consists of packing the material to be treated in a powdered mixture of alumina and chromium—45 per cent of alumina and 55 per cent of chromium, by weight. The material is usually packed into a tube of iron, which is then heated to from 1300 to 1400 degrees C. in hydrogen, vacuum, or some neutral atmosphere. Chromizing has been used on turbine buckets in

order to protect them against corrosion. By casehardening and heat-treatment chromized iron may be made very hard.

Chuck Closer. An "automatic" chuck closer is frequently used on bench lathes in connection with a turret and double-tool cross-slide, when operating on bar stock. This device is used in place of the regular draw-in spindle, and closes the collet chuck by simply throwing over a hand lever. The chuck-closing mechanism is applied at the rear end of the spindle and takes place of the usual handwheel. It enables the machine to be run continuously, as the work may be gripped or released while the lathe is in motion.

Chucking Machines. Some turret lathes are used exclusively for operating on bar stock which is fed through the hollow spindle and is held by some form of collet chuck located in the end of the spindle, whereas other machines are equipped either for handling bar stock or larger work which must be held in a regular chuck that is screwed onto the spindle. There are also turret lathes which are not arranged for turning parts from bar stock, but are designed exclusively for machining castings or forgings which must be held in a chuck that is screwed onto the spindle. Lathes of this latter class are frequently called *chucking* machines, owing to the fact that the work is always held in a chuck.

Multiple-spindle Chucking Machine: This is an automatic machine provided with a number of spindles, usually four or five, which carry and revolve the tools, while the work being machined is held stationary in a multiple-chuck turret which holds each part in line with one of the spindles and which is automatically indexed, so that the work passes from one spindle to another until it is finished. This type of machine is especially adapted for boring, reaming, and facing operations on castings or forgings which can readily be held in chuck jaws.

Chucking Reamers. Reamers of this class are so named because they are used largely for reaming parts held in the chuck of some machine such as an engine lathe or turret lathe. Chucking reamers are made in two general types: *fluted* chucking reamers and *rose* chucking reamers. The fluted type is used for enlarging drilled holes and finishing them true to size; the rose type is used for enlarging cored or drilled holes and is so constructed that a considerable amount of metal can be removed by it. See Rose Chucking Reamer.

Chucks. Chucks of various designs and types are used on different classes of machine tools, either for holding a part while it is being operated upon or for holding some form of cutting

tool. The chucks that are used on lathes and other types of turning machines hold and rotate the work, whereas the chucks of drilling machines hold and rotate drills, counter-bores, and other tools. Chucks vary greatly both in regard to their size and design. Some are of special construction and are intended for a limited class of work or for holding one particular part, although most work-holding devices of the latter class are known as jigs or fixtures, rather than chucks. The term "chuck," as applied in the machine shop, usually means a device which not only holds but rotates either the work or a cutting tool, although there are exceptions as, for instance, in the case of planer chucks which are attached to the planer table and travel with it. Most work-holding devices which are classified as chucks have gripping jaws that are adjustable in order to adapt the chucks for holding parts or tools of different sizes. These jaws are operated either by screws, by a combination of screws, or a spiral scroll and gearing, by compressed air, or by the engagement of conical surfaces which serve to move the chuck jaws radially by a wedging action. There are also magnetic chucks which do not require jaws, as the work is held by magnetic force instead of by mechanical means.

Chucks, Air-Operated Type. Air-operated chucks are used on some turret lathes, especially when a rapid power method of chucking is essential to economical production. Chucks operated in this way are especially desirable when the machining operation is rapidly performed and the work is required in large quantities. Such equipment is particularly adapted for brass work.

Chucks, Gear. Special chucks are commonly used for holding gears, especially when grinding the bores of heat-treated gears to insure accuracy between the bore and the teeth. The chuck may be designed to hold the gear (1) by contact at the pitch line; (2) by contact at the bottom of tooth spaces; (3) by contact with the outside diameter or tops of the teeth. The pitch-line contact may be obtained by means of rolls which serve as gripping jaws. Another type of chuck has accurate gears which serve as jaws and are tightened into mesh with the gear to be ground. The root control, or contact at the bottom of the tooth spaces, is obtained by means of special jaws which are narrow enough to bear only on the root. Some gear chucks for bevel gears have tapering pins for pitch-line contact and others, jaws for engagement at the bottoms of the tooth spaces. A third method consists in clamping the bevel gear against a master gear which meshes with the gear to be ground.

Chucks, Lathe. There are three classes of chucks ordinarily used on the engine lathe, known as the independent, universal,

and combination types. The *independent chuck* is so named because each jaw can be adjusted in or out independently of the others by turning the jaw screws with a wrench. The jaws of the *universal chuck* all move together and keep the same distance from the center, and they can be adjusted by turning any one of the screws, whereas, with the independent type, the chuck wrench must be applied to each jaw screw. The *combination chuck,* as the name implies, may be changed to operate either as an independent or universal type. The advantage of the universal chuck is that round and other parts of a uniform shape are located in a central position for turning without any adjustment. The independent type is, however, preferable in some respects, as it is usually stronger and adapted for holding odd-shaped pieces, because each jaw can be set to any required position. The *collet chuck* is another class which is commonly applied to tool-room lathes, turret lathes, bench lathes, etc., usually for holding rods or bar stock, which is inserted through the hollow spindle of the machine, so that the end projecting beyond the chuck may be operated upon.

Chucks, Magnetic. Magnetic chucks are unexcelled for holding a large number of small parts at one time for grinding and are also adapted for a wide range of work. They are made in a variety of sizes and shapes, the form depending upon the type of grinding machine and the shape of the work. The magnetic chuck is a special form of electromagnet which is connected by wires and a control switch with an electric power circuit. The surface, against which the work is held, has a series of positive and negative holes which are separated by an insulating material. When in use, the chuck is clamped onto the table of the grinder, and the work is held by magnetic force when the current is turned on. The rectangular magnetic chuck is the form used on surface grinders of the reciprocating type. Magnetic chucks are made in many different styles and shapes. Some are so arranged that the clamping face can be set at any angle for taper grinding and others have faces that are vertical. There is also the rotary type and other special designs. The rotary form is used when a continuous rotary movement is required, instead of a reciprocating motion.

Chucks, Quick-Change Type. The quick-change collet chuck is adapted for both drilling and tapping operations. With one arrangement the drill or tap is held in a collet and, in order to mount the tool in the chuck ready for use, it is merely necessary to grasp a knurled collar and hold it back against the rotation of the spindle. This causes a pair of retaining dogs to be drawn back into the body of the chuck so that the collet can be

slipped into place. The knurled collar is then released and the action of a spring forces the dogs inward, so that they engage a groove in the collet and secure it in the chuck.

Chucks, Vacuum. See Vacuum Chucks.

Cincinnati Plan. A system of engineering education in which the students, taking engineering courses at a technical college, work alternate weeks in regular manufacturing shops and in the school.

Cinnabar. Cinnabar is a very heavy mineral composed of red sulphide of mercury, found in California, Mexico, Spain, Hungary, Chile, and several other places. It is the principal and most valuable of the commercial mercury ores.

Circle. A plane area bounded by a curved line known as the *periphery* or *circumference,* all points of which are an equal distance from a point within the circle known as the "center." The term "circle" is also used with reference to the periphery or circumference only, without reference to the plane area enclosed by the circumference. The formula for a circle in Cartesian coordinates whose radius is r and whose center is at the origin is given as $x^2 + y^2 = r^2$ or $r = \sqrt{x^2 + y^2}$.

Circle Dividing. If there are six divisions, the dividers may be set to the radius of the circle. For any other number of divisions, the distance between the dividing points may be determined by the following rule: Divide 360 by the number of divisions required to obtain the angle between centers of the spaces; find the sine of one-half this angle (by referring to a table of sines) and multiply it by the diameter of the circle upon which the centers of the spaces are to be located. Assume that twenty equally spaced centers are to be located on a circle 10 inches in diameter; then the angle between the centers equals $360 \div 20 = 18$, and the sine of one-half this angle, or 9 degrees, is 0.15643; therefore the distance between the divider points equals $0.15643 \times 10 = 1\text{-}9/16$ inch, approximately.

Circuit-Breakers. A circuit-breaker is a device for automatically opening an electric circuit when a predetermined abnormal condition exists in the circuit in which the circuit-breaker is connected. Thus, it is generally designed to trip under one of the following conditions or some combination of them: Overload, underload, over-voltage, low voltage, and reverse current. The automatic tripping of a circuit-breaker is accomplished by applying or releasing the power of an electromagnet which is excited by current flowing through a coil of wire, or its equivalent, surrounding at least one pole of a magnetic circuit. The

magnet coils may be of either one of two classes—current or potential—depending upon the manner in which the coils are connected in the circuit. There are two main types of circuit-breakers in use: the air circuit-breaker and the oil circuit-breaker.

Air Circuit-breaker: In this type the circuit is broken in air or gas and various means are taken to prevent excessive arcing when heavy currents are interrupted. Thus, (1) an auxiliary set of carbon contacts may be used to take the final arc, (2) a magnetic "blowout" or intense magnetic field may be used to extend the path of the arc, thus aiding its rupture, (3) a de-ionizing device may be used which breaks up the single arc into a number of small arcs between de-ionizing plates, or (4) a blast of air or carbon dioxide may be used at high pressure to blow out the arc. Small air circuit-breakers have been widely introduced for use in place of plug fuses for the protection of lighting circuits. Large sizes are used in power circuits. See also: Switches, Air-break Type.

Oil Circuit-breaker: In this type of breaker the arc is interrupted under oil which provides a quenching effect. A de-ionizing element may be used to aid in the rapid extinguishment of the arc. See also: Switches, Oil Type.

Circular File. The circular form of file is intended more particularly for filing soft metal, such as aluminum, solder, babbitt, etc. This type of file is simply a steel disk on the sides of which teeth are cut. When the file is in use, it is mounted on a spindle like a grinding wheel and is rotated by power. A circular file 14 inches in diameter and 1 inch thick is rotated at a speed of about 200 revolutions per minute. The part to be filed is held against the side of the revolving file. There are several annular rows of teeth, the teeth in adjacent rows inclining in opposite directions. The grade of cut is varied to meet different requirements.

Circular Inch. The area of a circle 1 inch in diameter. One circular inch is equal to one million circular mils, or 0.7854 square inch.

Circular Measure. The system of angular measurement in which the *radian* is used as a unit. This system is generally used in theoretical investigations and in formulas relating to revolving bodies. See Radian.

Circular Mil. In measuring diameters and areas of electric wires, use is frequently made of the surface measurement *circular mil.* A circular mil is the area of a circle 0.001 inch in diameter; one circular inch equals the area of a circle 1 inch

in diameter; hence, 1 circular inch equals 1,000,000 circular mils. A circular inch equals 0.7854 square inch.

Circular Pitch. The *circular pitch* of a gear tooth is the distance from the center of one tooth to the center of the next, measured along the pitch circle. The circular pitch system is applied, as a general rule, only to gears with cast teeth which are not afterwards finished or cut, and to very large pitches. For cut gearing, *diametral pitch* is used almost exclusively, especially when the pitch is not coarser than one diametral pitch. When the pitch diameter and the number of teeth of a gear are known, the circular pitch is found as follows:

$$\text{Circular pitch} = \frac{\text{pitch diam.} \times 3.1416}{\text{number of teeth}}$$

Circular Saws. The circular saw is used for heavy work. It is quite similar to the familiar buzz saw found in woodworking shops, may be several feet in diameter, and often has teeth of tungsten carbide. The peripheral speed is relatively slow, 35 to 70 surface feet per minute, but the driving motor is powerful enough for a fairly rapid feed.

Sometimes circular saws are made without teeth or with only V-shaped nicks cut into the cutting edge. These are known as *friction saws* and operate at high speeds up to 20,000 surface feet per minute. With these saws, it is the speed of the blade, not the sharpness of the teeth, that is responsible for the cutting action. The speed is so high that the frictional heat developed is enough to soften the metal and allow the blade to go through it. The purpose of the nicks on the edge is to pick up and throw out the particles of softened metal.

Another type of circular saw is known as the *abrasive disc* and is actually a thin grinding wheel, rubber or resinoid bonded. Such discs are quite thin, about one-eighth inch, and operate at some 15,000 surface feet per minute. They wear down more rapidly than a steel saw but have a very rapid rate of metal removal and make a fine clean cut. Abrasive disc machines may operate by feeding the work in toward the wheel or by mounting the wheel on a swinging arm which the operator pushes or pulls across the stationary work. See also Cutting Off Stock with Abrasive Wheels.

Circumference. The curved line which forms the boundary line of any circular, elliptic or oval surface; specifically, the periphery of a circle.

Cistern Barometer. An instrument for measuring the pressure of the atmosphere, consisting of a glass tube about 36 inches long, hermetically sealed at the upper end at which a

vacuum is formed, the remainder of the tube containing mercury. The tube is placed with its open lower end in a cistern or vessel containing mercury, the pressure of the atmosphere being measured by the difference in the height of the mercury in the tube and in the cistern.

Citroen Gear. This type of gear might be described as a double herringbone form, as the teeth have a double wave formation such as would be obtained by placing two herringbone gears together. Gears of this type are used to a very limited extent as the herringbone gear has advantages in regard to cutting, and is, at least, equal to the Citroen gear from a practical or operating point of view.

Clack Valves. Pump valves of the *clack* or *clapper* type are hinged on one side so that they open and close like a door. The pivot of the hinge sometimes has an elongated hole so that the valve can lift at the hinged end so as to obstruct the flow of liquid as little as possible. Many valves of the clack form are of metal and have leather faces. When two clack valves are hinged at the center of a valve-seat, the term "butterfly" valve is often used. The *flap valve* is similar to a clack valve, except that it is fastened to one side of the valve opening instead of being hinged, and is formed of material that has sufficient elasticity to bend far enough to give the required port opening. These valves are usually made of rubber.

Clad Metals. Clad metals are metals that are composed of base metals faced with another metal on one or both sides. The facing metal is integrally bonded to the base metal. They were developed to make economical use of the surface properties of certain expensive metals.

Many clad metals are produced in sheet or plate form. In some cases the facing metal's cost would be prohibitive if it were used in the solid form. Clad metals provide the advantages of corrosion resistance or conductivity (facing metal) together with formability or strength (base metal).

Typical clad metals are Alclad metals, a group of wrought metals that have facings of high-purity aluminum which provide protection against corrosion.

Clad metals are also being produced with facings of plastic. Parts made of these may be stamped, embossed, or formed into intricate shapes without having any adverse effect on the plastic coating.

Clam-Shell Brake. A block brake provided with two blocks acting one on each side of the brake pulley. It is often used in place of a band brake, over which it possesses the advantage of

even wear on the blocks and of a positive release, but it does not have as great a gripping power as a band brake.

Clark Cell. A primary cell or battery, known as a "standard" cell, used for obtaining a certain standard value of electromotive force under given conditions. It consists of a glass container mounted in a metal case, having insulated binding posts connected to platinum terminals. In one form, mercury, which is the negative electrode, is placed at the bottom of the cell, and a paste of mercurous sulphate and zinc sulphate is placed upon the mercury, the zinc plate, which is the positive electrode, being partly immersed in it, and then saturated zinc sulphate solution is put on top, the latter acting as the electrolyte while the paste acts as the depolarizer. The surface is usually covered with cork and the cell sealed. Platinum wire led through the bottom of the cell forms the terminal for the negative electrode, and insulated wire led through the cell forms the terminal for the positive electrode. The electromotive force is 1.4322 volts at 15 degrees C. (59 degrees F.).

Clay Crucible. A pot or container used in the steel industry in the manufacture of crucible steel, having a capacity of from 75 to 100 pounds of metal. Clay crucibles are made of a high quality of clay mixed with about 5 per cent of powdered coke. They must be heated slowly to prevent cracking, and must be recharged while hot.

Cleaning Machines. Machines for cleaning and drying screw machine parts, stampings, etc., are made in several different designs. One machine consists of a revolving horizontal cylinder through which the parts pass during the cleaning or drying operation. As the parts pass from a chute into one end of the cylinder they are moved along by a helical or screw-shaped conveyor and the cleaning solution is scooped up from a tank below and poured on to the work. As the cylinder rotation continues, the work advances and is further cleansed by fresh solution and finally, when cleaned, reaches a perforated section of the cylinder. The solution then drains back into the tank. The parts are next rinsed with water and then pass into a larger perforated section where they are dried by means of hot dry air obtained by means of steam coils and a blower. Finally the parts pass out at the discharging end, the entire operation having been continuous and automatic.

Cleaning Metals, Electrochemical. See Electrochemical Cleaning.

Cleaning Solution, Soda. See Soda Cleaning Solution.

Clearance. "Clearance" is a term signifying the allowance between working parts to admit of motion and lubrication. In other words, the clearance is the space between adjacent parts, whether this space is allowed merely to avoid interference, or in order to obtain definite classes of free fits. The clearance allowed between different parts is governed by the conditions under which the parts are to work.

Clearances are vital factors in interchangeable manufacturing. Fits can be secured without interchangeability, but the latter cannot be maintained without proper clearances. It is self-evident that a certain space must be left between operating parts. The minimum clearances should be as small as the assembling of the parts and their proper operation under service conditions will allow. The maximum clearances should be as great as the functioning of the mechanism permits. The variation between a maximum and a minimum clearance determines the manufacturing tolerance. It is clear, then, that determining at the outset the permissible clearances establishes also the extent of the tolerances which control the final inspection.

Clearances should be one of the principal considerations in developing the manufacturing design. This design should aim to allow the greatest possible amount of clearance between companion parts. The more the design lends itself to this end, the greater the economy of manufacture and the greater the degree of interchangeability obtainable. In determining which parts of a mechanism can be made interchangeable, this matter of permissible clearances plays the largest part. A mechanism which is so designed that it cannot permit fairly liberal clearances is not a suitable one to be manufactured on a strictly interchangeable basis. Every operating part of a mechanism must be located within reasonably close clearances in each plane. After such requirements of location are met, all other surfaces should have liberal clearances, unless the factor of strength is the controlling one.

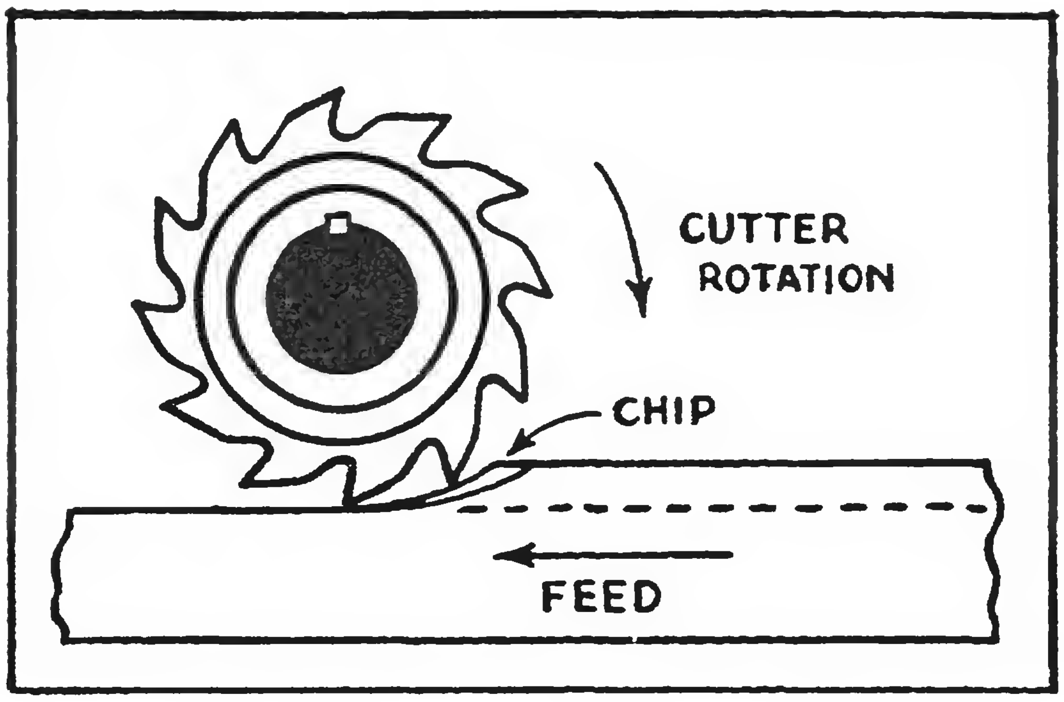
Clearance Drill. When a machine screw or cap-crew is used to fasten one machine part to another, the hole in the untapped part is drilled slightly larger in diameter than the outside or body diameter of the screw. This is done in order to provide a slight amount of clearance; hence, the drill used is known as a clearance drill. Assume that No. 6 machine screws are to be used for attaching a plate to a casting. The outside diameter of this screw is 0.138 inch, and the size of the clearance drill might be No. 27 or No. 25.

Clearance for Cutting Tools. In order that the cutting edge of a turning tool, drill, milling cutter or other edged tool for

metal cutting, may work without interference, it must have clearance; that is, the surface below or back of the cutting edge must be ground to a certain angle so that it will not rub against the work and prevent the cutting edge from entering the metal. This clearance should be just enough to permit the tool to cut freely. A clearance angle of 8 or 10 degrees is about right for lathe turning tools. A turning tool for brass or other soft metal, particularly where considerable hand manipulation is required, could advantageously have a clearance of 12 or 14 degrees, as it would then be easier to feed the tool into the metal; but the clearance for various classes of metal-cutting tools should be just enough to permit them to cut freely. Excessive clearance weakens the cutting edge and may cause it to crumble under the pressure of the cut. The angle of clearance is about 4 or 5 degrees for planer tools, which is much less than that for lathe tools. This small clearance is allowable because a planer tool is held about square with the platen, whereas a lathe tool, the height of which may be varied, is not always clamped in the same position. A lathe tool also requires more clearance because it has a continuous feeding movement, whereas a planer tool is stationary during the cut, the feed taking place just before the cut begins.

Cleveland Grip Sockets. The grip socket known as the *Cleveland grip socket* is designed to hold and drive taper shank drills and other tools provided with taper shanks. A groove is milled in the shank of the drill or tool and a key which is let into the body of the socket fits into the groove and is locked securely in place by turning a revolving collar one revolution. When the key is locked, it is impossible for the tool to slip in the socket or to be pulled out until the collar is turned back again to release the key.

Climb-Cut Milling. In milling, the feeding movement and cutting movement are in *opposite* directions, as a general rule. This is sometimes known as the "normal" or "conventional" method of milling to distinguish it from the climb-cut method. The term *climb-cut* or *climb* milling means that the feeding movement of the work and the cutting movement are in the same direction. Several advantages are claimed for climb-cut milling, assuming that conditions are favorable to its application. One important advantage cited is that the cutter life is increased and at the same time higher speeds and feeds may be employed. When the cutter rotation is against the feeding movement (as in the conventional method) the cutting edge of each tooth rubs against the work or rides upon it momentarily before beginning to cut, which results in greater dulling of the cutter than when each cutting edge enters the metal at the top of the cut or at the



point of greatest chip thickness. The advantage of the climb-cut method is said to be even greater for the harder materials, although there may be an exception when castings have a hard sandy scale.

Climb-cut milling has another important advantage in that it enables pieces that are difficult to clamp securely in a fixture or on the machine table to be milled efficiently. The downward action of the cutter teeth in climb milling such pieces tends to seat them firmly in the holding devices. Cutters used in the conventional manner would tend to lift the pieces from their seats and might make the operation impractical. It is evident that a machine used for climb-cut milling must be in good condition and be so constructed that the machine table will resist the cutting forces in either direction. Any play or lost motion which would permit the cutter to climb into the work faster than intended would, of course, be objectionable.

Clock Brass. A brass suitable for the gears in clocks, containing about 60 per cent of copper, a small percentage (not exceeding 1.5 per cent) of lead, and the remainder zinc.

Closed-Circuit Oiling. A method of bearing lubrication generally used for high-speed work, in which the oil is used over and over again. After dropping off from the journal to a collecting reservoir, the oil is filtered and used again by being automatically supplied to the journal at a suitable point. A cooling arrangement is sometimes fitted to the reservoir, so as to remove the heat from the oil.

Closer or Step Chuck. See Step Chuck.

Cluster Gears. The term "cluster gears" is applied when two or more gears are formed on one solid piece. Cluster spur gears are commonly used in automobile transmissions and other geared

speed-changing mechanisms because they are stronger and more compact than single gears fastened together.

Clutches. A clutch is a form of coupling which is designed to connect or disconnect a driving or driven member for starting or stopping the driven part. A clutch consists principally of two main sections which are engaged or disengaged either at will by a hand-operated controlling device, or automatically by the action of some power-driven mechanical apparatus, such as a cam connected by suitable means with the shifting clutch member. There are several distinct types of clutches which are made in a great variety of designs. The common types of clutches may be divided into two general classes; namely, (1) those having teeth which interlock, or positive clutches, and (2) those which transmit motion from the driving to the driven part of the clutch by frictional contact.

When motion is transmitted from the driving to the driven parts of a clutch simply by frictional contact, the load may be started gradually and without shock, such as often occurs when a positive clutch is engaged. The different types of friction clutches vary in regard to the form of the friction surfaces and with respect to the kinds of material used to obtain sufficient frictional resistance. The frictional surfaces may be either conical or cylindrical, or in the form of one or more flat rings or disks.

Conical Clutches: A conical clutch is so designed that motion is transmitted by the frictional resistance of engaging conical surfaces. The effectiveness of any friction clutch as a transmitter of power varies with the coefficient or degree of friction between the engaged surfaces. The frictional surfaces may both be of metal, but, in many cases, one member has a metal surface and the other is partially or entirely covered with some material such as leather or an asbestos fabric. The cast iron and leather combination is common, and pieces of cork inserted in holes drilled in one member is another common method of increasing frictional resistance. It is common practice to maintain the driving and driven members of friction clutches in engagement by means of springs which are compressed in order to release the clutch. The angle of the conical surfaces is usually about 12 or 13 degrees. The conical type of friction clutch is simple in construction but rather bulky or large when compared with other types of equal capacity as transmitters of power.

Expanding Type of Friction Clutch: The radially expanding type of clutch is a form that has been widely used, the details of the design being varied more or less. A typical design consists of an outer casing in which there are two expanders or segment-

shaped pieces connected by right- and left-hand screws, respectively. These screws are attached to levers, which, in turn, are connected to the sliding sleeve, by links, thus forming toggles between the sleeve and the screws. The two expanders and the toggle mechanism are caused to revolve with the shaft by a central driving hub. The clutch is operated by shifting the sliding sleeve and toggles; this movement turns the screws having right- and left-hand threads far enough to either expand the inner members tightly against the outer casing or to withdraw them from frictional contact. The expanders may be lined with maple grips, to increase the frictional resistance.

Ring and Disk Clutches: Many clutches of the friction type transmit motion from the driving to the driven side through the frictional resistance of rings, plates, or disks which are pressed together, the resistance being between the flat surfaces of the rings or disks which are thus held in contact. Some clutches of this general type have a few comparatively heavy rings, whereas others are equipped with a larger number of thin rings. By using quite a number of disks or rings instead of one or two, the diameter of the clutch may be reduced without sacrificing the contact area or the amount of frictional surface. Various combinations of materials are used for the disks of multiple-disk clutches. One set, for example, may be of soft steel and the other of phosphor-bronze, and in other types one set of disks is faced with some special friction material such as asbestos wire fabric, as in the case of dry plate clutches, the disks of which are not lubricated like those of a clutch having, for example, the steel and phosphor-bronze combination. See also Induction Clutch, Magnetic Clutch.

Clutches that Automatically Disengage. The clutches used on power presses and some other kinds of machines are designed to automatically disengage after making one or more revolutions. The clutch connects the fly-wheel or driving gear of the press with the driven shaft, whenever it is tripped, by pressing down a foot-treadle. As long as this treadle is held down, the clutch remains in engagement and the press continues to run; if the treadle is released, the clutch is disengaged when the ram or slide of the press is approximately at the top of its stroke. The downward movement of the treadle releases a pin, key, or some other form of locking device which quickly engages the driving member; when the treadle is released, the locking device encounters some form of trip or cam surface which withdraws it and stops the press. There are many designs of clutches of this general type.

Coal. Coal, in the ordinary sense of the word, includes a number of carbonaceous materials used as fuel. The different

kinds of coal all contain carbon, hydrogen, oxygen, and nitrogen, forming a carbonaceous or combustible portion, and also some matter which remains after the combustion in the form of ash. The amount of ash varies considerably in different kinds of coal. The nearest approach to pure carbon is furnished by anthracite coal which contains over 90 per cent of this constituent. Coals of this kind burn with a very small flame, producing intense local heat and no smoke. Bituminous coal contains from 50 to 85 per cent of carbon. Lignite or brown coals have a comparatively low percentage of carbon, usually not exceeding 50 per cent, while the oxygen and hygroscopic water is high.

The U. S. Geological Survey classifies coal as anthracite, semi-anthracite, semi-bituminous, bituminous, sub-bituminous, and lignite.

Anthracite contains over 90 and sometimes up to 97 per cent of carbon and has a heating value per pound of combustible of from 14,500 to 15,000 B.T.U. Anthracite is hard and shiny, is slow to ignite, and burns slowly.

Semi-anthracite coal is similar to anthracite. It contains from 85 to 90 per cent of carbon and has a heating value, per pound of combustible, of from 14,500 to 15,500 B.T.U. It is not as hard as regular anthracite, is less shiny, and burns more rapidly.

Semi-bituminous coal contains from 75 to 85 per cent of carbon and has a heating value of from 15,500 to 16,000 B.T.U., per pound of combustible. This coal is softer than the anthracites and has a tendency to produce more smoke, but on account of its high heating value it is one of the best coals to use for power plant purposes.

Bituminous coal, generally known as soft coal, contains from 50 to 75 per cent of carbon and a large percentage of volatile matter, varying from 25 to 50 per cent. The heating value per pound of combustible is from 13,500 to 15,500 B.T.U. Coal of this kind gives out large volumes of smoke, and requires special care in firing and furnaces constructed so as to prevent smoke as far as possible.

Lignite, also known as *brown coal,* contains less than 50 per cent of carbon and over 50 per cent of volatile matter, and has a heating power per pound of combustible of from 11,000 to 13,500 B.T.U. Two types of lignite are recognized: (1) *sub-bituminous* coal, also known as *lignite, black lignite, brown coal, lignitic coal,* etc.; this kind resembles bituminous coal, is black and shiny, but disintegrates more rapidly than bituminous coal when exposed to the air, and its heating value is not as high as that of bituminous coal; (2) *lignite,* also known as *brown lignite* or *brown coal,* is distinctly brown in color and has a woody struc-

ture. It carries from 30 to 40 per cent of moisture and has a lower heating value than any of the other coals. It is, in fact, intermediate between coal and peat, and is fragile, splitting into small pieces when exposed to the air.

Coal and Gas Fuel-Oil Equivalents. See Fuel-oil Coal and Gas Equivalents.

Coal Combustion. See Combustion of Coal.

Coal Dust as Fuel. The fact that dust will burn with great rapidity accounts for the attempts to make use of pulverized fuel, which may be burned without smoke and with high economy. This fuel, instead of being introduced into the firebox in the ordinary manner, is first reduced to a powder by pulverization, and, in place of the ordinary boiler firebox, a combustion chamber is used in the form of a closed furnace lined with firebrick. This furnace is provided with an air injector having a nozzle which throws a constant stream of powdered fuel into the chamber, spraying it throughout the whole space of the firebox. This powder may be ignited by first raising the lining of the firebox to a high temperature by an open fire. The combustion of the powdered fuel then continues in an intense and regular manner under the action of the air current which carries it into the combustion chamber. It is probably the most economical method of burning coal as far as fuel efficiency alone is concerned. It is the most expensive method in regard to the auxiliary equipment and labor required and the necessity of various features being carefully looked after. The coal must have about 30 per cent of volatile matter and be pulverized to a certain degree of fineness in order to ignite satisfactorily. It cannot be stored for more than about a day without danger of spontaneous combustion. This makes necessary an elaborate system of conveyors to carry the coal from the pulverizers to the furnaces. In general, this is an impracticable system for small installations, but may be sufficiently economical to be very desirable for large installations.

Coal Gas. See Gas Production.

Coarse Metal. A mixture of copper and iron sulphide obtained in the smelting of copper ore in a blast or reverberatory furnace. It is also known as *matte*.

Coarse-Threading Attachments. See Thread-cutting Attachments for Large Leads.

Cobalt. Cobalt is one of the metallic elements; its chemical symbol is Co, and its atomic weight, 59. Its specific gravity varies from 8.52 to 8.95, according to its state of purity. The specific gravity of unannealed pure metal is 8.79 and of annealed pure metal, 8.81, whereas the commercial metal has a specific gravity

of about 8.65. Its melting point is 1490 degrees C. (2714 degrees F.). The electric conductivity (silver = 100) is about 17. It is very magnetic, and ranks next to iron as a magnetic metal. The mean specific heat between 15 and 100 degrees C. (59 and 212 degrees F.) is 0.105. The hardness of cast cobalt is considerably greater than that of iron and nickel. The tensile strength of pure cast cobalt is about 34,000 pounds per square inch. This strength is raised to 37,000 pounds per square inch by annealing, and may be increased to 100,000 pounds per square inch by rolling and drawing into wire. The elastic limit is fairly close to the breaking load, and is considerably greater, proportionately, than that of iron or nickel. The addition of carbon to cobalt increases its tensile strength. The compressive strength of pure cast cobalt is 120,000 pounds per square inch. The impurities of commercial cobalt (up to 0.3 per cent of carbon in addition to small percentages of nickel, iron, sulphur, and silicon) raise the compressive strength to 175,000 pounds per square inch. The elastic limit in compression is, however, not more than about 50,000 pounds per square inch.

Cobaltcrom Steel. A tungstenless alloy or high-speed steel is known as cobaltcrom steel because it contains cobalt and chromium in addition to carbon. A typical steel of this kind contains about 1.5 per cent carbon, 12.5 per cent chromium, and 3.5 per cent cobalt. This steel can be hardened at a temperature of about 1830 degrees F., which is considerably lower than that required for high-speed steels containing tungsten. This lower hardening temperature for cobaltcrom is considered an important advantage in heat-treating tools having fine edges, such as milling cutters, reamers, taps, etc. Cobaltcrom tools are held at a temperature of about 1830 degrees F. until thoroughly "soaked"; then the temperature is reduced about 50 degrees, the tools are withdrawn from the furnace and allowed to cool in the atmosphere until the red color disappears, when the tools are quenched in oil until cold. Tools subject to shocks, such as pneumatic rivet sets, shear blades, etc., should be heated slowly to 1650 degrees F., the temperature then being reduced to about 1610 degrees F. The tool is then removed and permitted to cool in the atmosphere. There is no appreciable scaling in the heat-treatment of cobaltcrom steel. This steel can be cast in molds for making milling cutters, reamers, etc., in order to avoid fluting operations and permit finishing the tools by grinding.

Coefficient. In general a coefficient is a number prefixed to some other quantity by which this quantity is multiplied. In algebraic expressions, it is the number written at the left of a symbol and serves as a multiplier. Hence, in the expression

"3a," the figure "3" is the coefficient. A coefficient may also be expressed, in algebra, by a letter.

Coefficient of Expansion. Coefficient of linear expansion is the amount of expansion per unit of length due to an increase in temperature of one degree. The coefficient of cubical expansion is the amount of expansion per unit of volume for an increase in temperature of one degree. See Expansion.

Coefficient of Friction. The coefficient of friction is the ratio between the resistance to motion of a body due to friction, and the perpendicular pressure between the sliding and fixed surfaces. See Friction.

Coiling Springs. See Spring Coiling.

Coining Pressures. Special embossing or coining presses are required for many embossing operations in the manufacture of medals, jewelry, coins, silverware, etc. For such work as embossing coins or medals, enormous pressures are required in order to make the metal flow into every minute impression in the coining punch and die. The following pressures are required for embossing United States currency: Silver dollar, 160 tons; gold eagle, 110 tons; silver half-dollar, 98 tons; gold half-eagle, 60 tons; silver quarter-dollar, 60 tons; nickel, or five-cent piece, 60 tons; copper cent, 40 tons; dime, 35 tons. It will be noted that the gold half-eagle, silver quarter, and five-cent piece require the same pressure, although the sizes and weights differ greatly, thus indicating the comparative coining properties of gold, silver, and nickel.

A sharp impression depends upon pressure but also to a very great extent upon die construction. Fifty tons can bring up a sharper, better looking job than five hundred if the dies are arranged to pinch just where the sharp lines are desired, and relieved elsewhere, so that the metal can flow.

Coining Process of Forging. See Forging by Coining Process.

Coke. Coke is a product obtained by heating coal in air-tight retorts to such a temperature that the volatile constituents are driven off; hence, coke consists mainly of carbon, together with the incombustible materials or ash contained in the coal, and also small amounts of oxygen, hydrogen, and nitrogen, generally not exceeding 2 or 3 per cent. Coke, when produced rapidly and at a low heat, as in gas making, is of a dull black color, igniting with comparative ease, but when produced by long-continued heat, as in making coke for iron and steel melting, it is hard and dense, has a brilliant luster and silver-gray color, and will only burn in furnaces provided with strong draft. This quality is brittle and

hard. One pound of coal will yield from 0.35 to 0.90 pound of dry coke, depending upon the kind of coal from which it is made. Coke is an important fuel in blast furnaces and foundries, but its cost is high, and for that reason it is not used for power plant purposes. Coke is classified either as foundry coke or furnace coke.

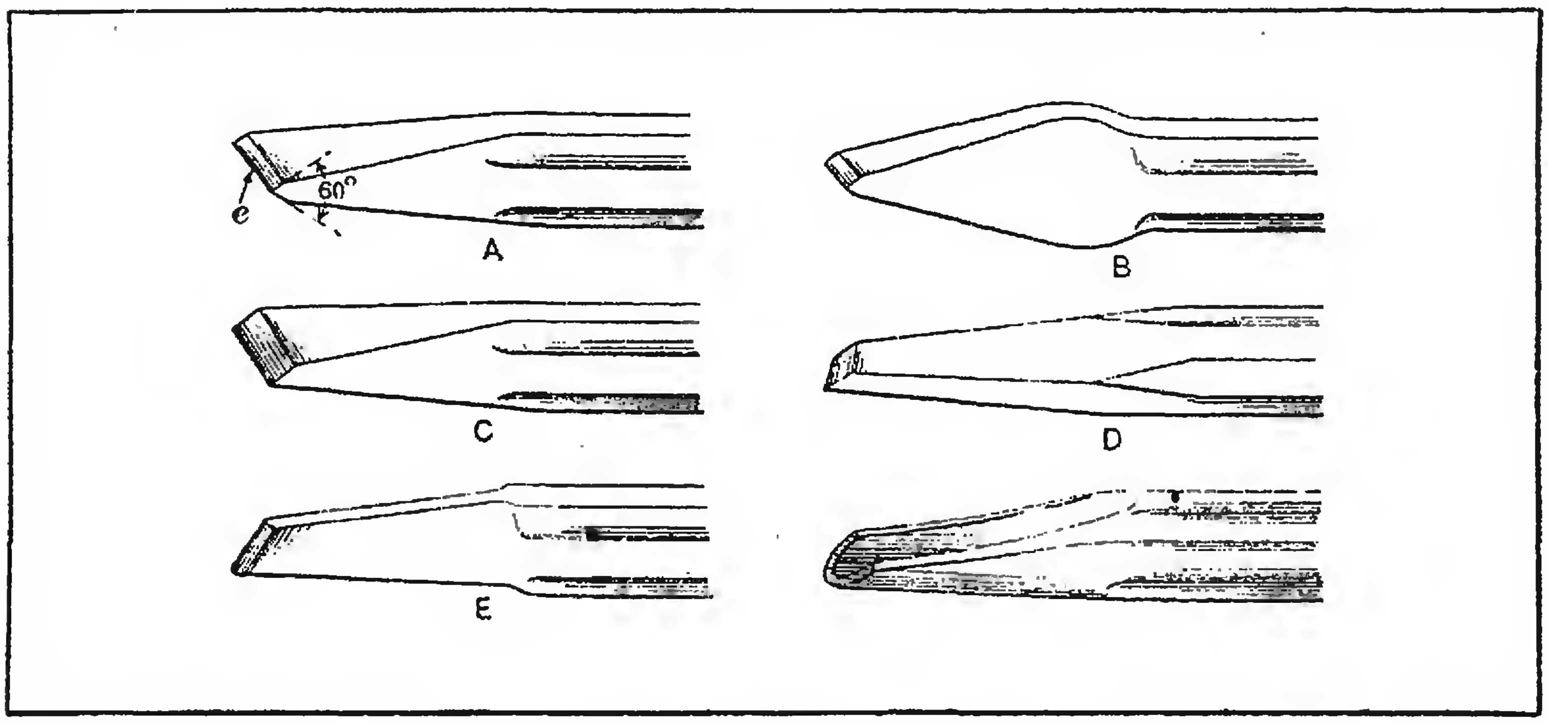
Foundry coke is a hard coke with a brittle surface. It is used in cupola furnaces for melting iron and in large forge furnaces for heating iron and steel. Foundry coke is dense, has a brilliant luster and silver-gray color, and will only burn in a furnace provided with strong draft. Generally, only coke that has been heated for seventy-two hours, while making, is classified as foundry coke. *Furnace coke* is sometimes used in cupola furnaces, but is mainly employed for the melting of ore in blast furnaces. While being made it is heated for forty-eight hours. The standard quality of foundry and furnace coke should not contain more than 13 per cent of ash, and not more than 1 per cent of sulphur. When foundry or furnace coke contains more than 1.2 per cent of sulphur, it is generally known as *smelter coke.* This quality of coke should not be used for smelting or melting iron, but has no disadvantages for use in the smelting of most of the non-ferrous ores. The cullings from foundry and furnace coke, that is, the part of the coke next to the back and front of the oven and around the oven doors, is generally known as *soft coke, heating coke,* or *jamb coke.* Coke obtained as a by-product in gas works is known as *gas coke.* Crushed coke is graded and placed on the market according to size, and is divided into the following classes; egg, large stove, small stove, chestnut, ⅞-inch pea, ½-inch pea, and dust coke or coke breeze. The egg, large and small stove and chestnut coke is used in small forge furnaces. The pea sizes are used in chemical works, and the coke dust is used for covering the bottoms of soaking pits and crucible furnaces to protect the brickwork.

Coke Breeze. Pulverized coke mainly used for covering the bottoms of soaking pits and crucible furnaces for protecting the brickwork. It is also known as *coke dust.*

Coking Coal. Coke is the fuel commonly used in blast furnaces, and its purity, strength to resist crushing excessively under the blast furnace load, and porosity to permit free circulation of the gases, are important qualities which depend upon the kind of coal used in making the coke. The difference between coking and non-coking bituminous coals has been explained as follows: If the tars of the coal fuse and run at a temperature lower than that at which they volatilize or are driven off as a gas, then the coal may be said to be a coking coal. In this event, the freed tars

permeating the fuel bed induce the formation of coke masses by closure of fuel particles and exclusion of air. Conversely, if the tars of the coal are of such composition that they volatilize and are driven off as a gas before they fuse and run through the fuel bed, the coal is then said to be a non-coking or a free-burning coal.

Colaweld Mormetal. A coating material that can be applied with a spray, brush, or as a powder and then heated by oven, torch, or other means to produce a fusion bond. High resistance to corrosion, abrasion, and erosion is provided. Zinc, cadmium, tin, bismuth, lead, and their alloys can be applied to ferrous and non-ferrous metals by this process. Useful for high-speed production in the fields of marine construction, transportation, building and general maintenance.



Different Types of Cold Chisels

Cold Chisels. The various types of "cold chisels" commonly used for chipping metals are shown in the illustration. The *flat chisel A* is used for a general class of work. The cutting edge *e* is either ground straight for light work or made slightly convex for heavy chipping to prevent the corners from breaking. The included angle at the end should be about 60 degrees, although a greater or less angle is advisable when the metal is either exceptionally hard or soft. A *cape chisel* is shown at *B*. This has a narrower cutting point than the flat chisel, and is used principally for cutting grooves, etc. The *side chisel C* differs from the flat type *A* in that it is ground and beveled on one side only, which permits it to be used on surfaces which could not be reached with a double-angle end; it is also used for chipping the sides of keyways, slots, etc. The *diamond point* shown at *D* is adapted to chipping V-grooves, squaring corners, etc., while the grooving

chisel *E* is for cutting oil grooves or for similar work. The *half-round chisel F* is known as a gouge, and, as its shape indicates, is used on curved surfaces.

Cold-Drawing. Cold-drawing, frequently, but erroneously referred to as cold-rolling, is a process to which round, square, or hexagonal bars may be subjected in order to improve the physical properties of the surface, to produce bars of accurate dimensions, and to obtain smooth, even surfaces. The process is briefly as follows: The ordinary hot-rolled bars are first pickled in order to remove the scale. They are then cold-drawn through dies and straightened.

Very little bar stock is cold-rolled today, and although the term "cold-rolled" is still generally used, nearly all the material known as "cold-rolled" is actually cold-drawn. A few manufacturers cold-roll bars over 4½ or 5 inches in diameter, but the general practice on large-diameter bars, especially shafting, is to turn and polish rather than to cold-roll. The largest tonnage of cold-rolled material is in strip stock.

Objects of Cold-finishing: The objects of both cold-drawing and cold-rolling may be one or more of the following: (1) To secure accuracy of size; (2) to obtain a smooth, even surface; (3) to produce thin, complicated sections; or (4) to affect the physical properties.

Dies for Cold-drawing: The dies are generally made of a special alloy tool steel that is very high in carbon, some analyses running as high as 2 per cent. Dies for rounds are solid; those for squares, hexagons, and flats are made up of sections, as are most dies for special sections. The Brinell hardness will run from 500 to 600, the harder die being desired for the smaller sizes. The life of a die averages about twenty-five coils on alloy-steel-wire sizes. On bars 20 to 30 feet in length, the average life will be about 500 bars.

Drawing the Steel: The drawing machines are horizontal benches, driven by individual motors. The grip or jaws, which take hold of the pointed end of the bar, engage with an endless chain which draws the material through the die. For wire sizes or coils, two types of drum machines are used. On one the axis of the drum is horizontal. This is used for the larger sizes of coiled stock—from about ½ inch to 1 inch; it is generally called a "bull block." The drums for drawing smaller sizes (from ⅜ inch down) have the axis of the drum vertical. These are the wire blocks. In wire mills, one operator may have charge of a number of drums, just as in a machine shop, one man may operate several automatic machines.

Reduction in Drawing: The draft or reduction per pass varies with the size, analysis, and finish desired. The usual practice is

to reduce the diameter 1/16 inch on sizes down to 5/16 inch. Under 5/16 inch, the reduction is generally 1/32 inch. This applies to such steels as screw stock, whether drawn in the hot-rolled, annealed, or heat-treated condition. In some cases, the reduction will be greater than 1/16 inch, and at other times less than 1/32 inch.

Finishing the Bars: After the material comes from the draw-bench, it must be straightened and cut to length. Straightening is most often done in a roll straightener, of which there are several types. In one type, the rolls that do the straightening revolve about the bar as it is fed through the machine. In another, the bar rotates as it moves between the rolls. The principle is that of deflecting the bar, first in one direction and then in the opposite direction, equal distances. The straightening also increases the smoothness of the bar; but if a high polish is desired, the bar will have to be passed through the machine several times.

Effect on Physical Properties: The effect of cold-drawing upon the physical properties of carbon steel is to increase the elastic limit 60 to 100 per cent and the ultimate strength 20 to 40 per cent, and to decrease the elongation and reduction of area. The effect of cold-drawing upon hot-rolled alloy steel is not so marked, but it causes an appreciable increase in the elastic ratio. The difference is not so great when the bars are heat-treated. Generally, alloy steel heat-treated bars, after cold-drawing, will show an increase of 10 to 25 per cent in elastic limit and ultimate strength, and a decrease in the elongation and reduction of area.

Tolerances: The tolerances for cold-drawn shafting usually vary from 0.002 to 0.004 inch, the tolerance increasing with the size of the shafting. For shaft diameters less than 2½ or 2 inches, the tolerance according to common practice would be minus 0.002 or 0.0025 inch and the plus tolerance, zero. For larger shafts, the minus tolerance would be 0.001 or 0.0015 inch per inch of shaft diameter and the plus tolerance, zero.

Cold Extrusion. In simplest terms, cold extrusion can be defined as the forcing of unheated metal to flow through a shape-forming die. It is a method of shaping metal by plastically deforming it under compression at room temperature while the metal is within a die cavity formed by the tools. The metal issues from the die in at least one direction with the desired cross-sectional contour, as permitted by the orifice created by the tools.

Cold extrusion is always performed at a temperature well below the recrystallization temperature of the metal (about 1100 to 1300 degrees F. for steel) so that work-hardening always occurs. *In hot extrusion,* recrystallization eliminates the effects

of work-hardening, unless rapid cooling of the extrusion prevents recrystallization from being completed.

Extrusion differs from other processes, such as drawing, in that the metal is always being pushed under compression and never pulled in tension. As a result, the material suffers much less from cracking. While coining is closely related to extrusion, it differs in that metal is completely confined in the die cavity instead of being forced through openings in the die. Some forging operations combine both coining and extrusion.

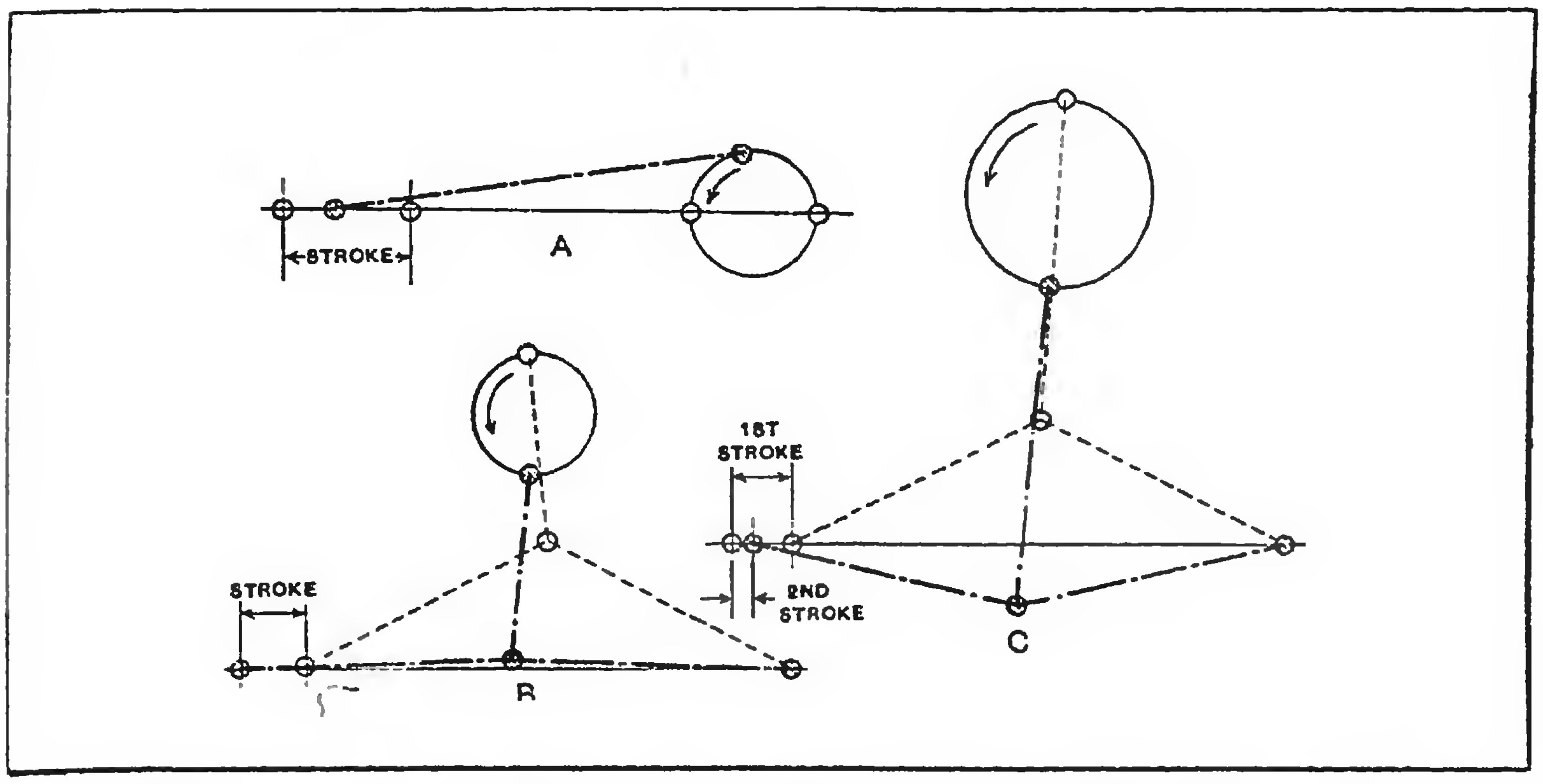
The pressure of the punch against the metal in an open die, and the resultant shaped part obtained by displacing the metal along paths of least resistance through an orifice formed between the punch and die, permits considerably higher deformation rates without tearing and large changes in the shape. Extrusion is characterized by a thorough kneading of the material. The cross-sectional shape of the part will not change due to expansion or contraction as it leaves the tool orifice. The term "cold extrusion" is not too descriptive and is not universally accepted. Other names for the same process include *impact extrusion, extrusion-forging, cold forging, extrusion pressing,* and *heavy cold forming.* Impact extrusion, however, is more frequently used to describe the production of non-ferrous parts, such as collapsible tubes and other components, while cold extrusion seems to be preferred by manufacturers of steel parts. In Germany, the practice is called Kaltspritzen—a literal translation of which is "cold-squirting."

One probable reason for not using impact extrusion in referring to the cold extrusion of steel is that the term implies plastic deformation by striking the metal an impact blow. Actually, the metal must be pushed through the die orifice, with pressure required over a definite period of time. One disadvantage of the terminology "cold extrusion" is the possible confusion with the older, more conventional direct extrusion process in which billets of hot metal are placed in a cylinder and pushed by a ram through a die (usually in a large, horizontal hydraulic press) to form rods, bars, tubes, or irregular shapes of considerable length.

Another possible disadvantage is the connotation of the word "cold." While the process is started with blanks, slugs, tubular sections, or pre-formed cups at room temperature, the internal, frictional resistance of the metal to plastic flow raises the surface temperature of the part to 400 degrees F. or more, and the internal temperature even higher (depending on the severity of the operation). These are still below the recrystallization temperature and the extrusions retain the advantages of improved physical properties resulting from the cold working.

Cold-Forging. See Cold Extrusion.

Cold-Headers. The design of cold-heading machines is based upon two distinct principles for reciprocating the movable ram of a cold-header: The crank principle, and the toggle principle. The crank principle is employed on most single-stroke machines and by at least one manufacturer for double-stroke machines as

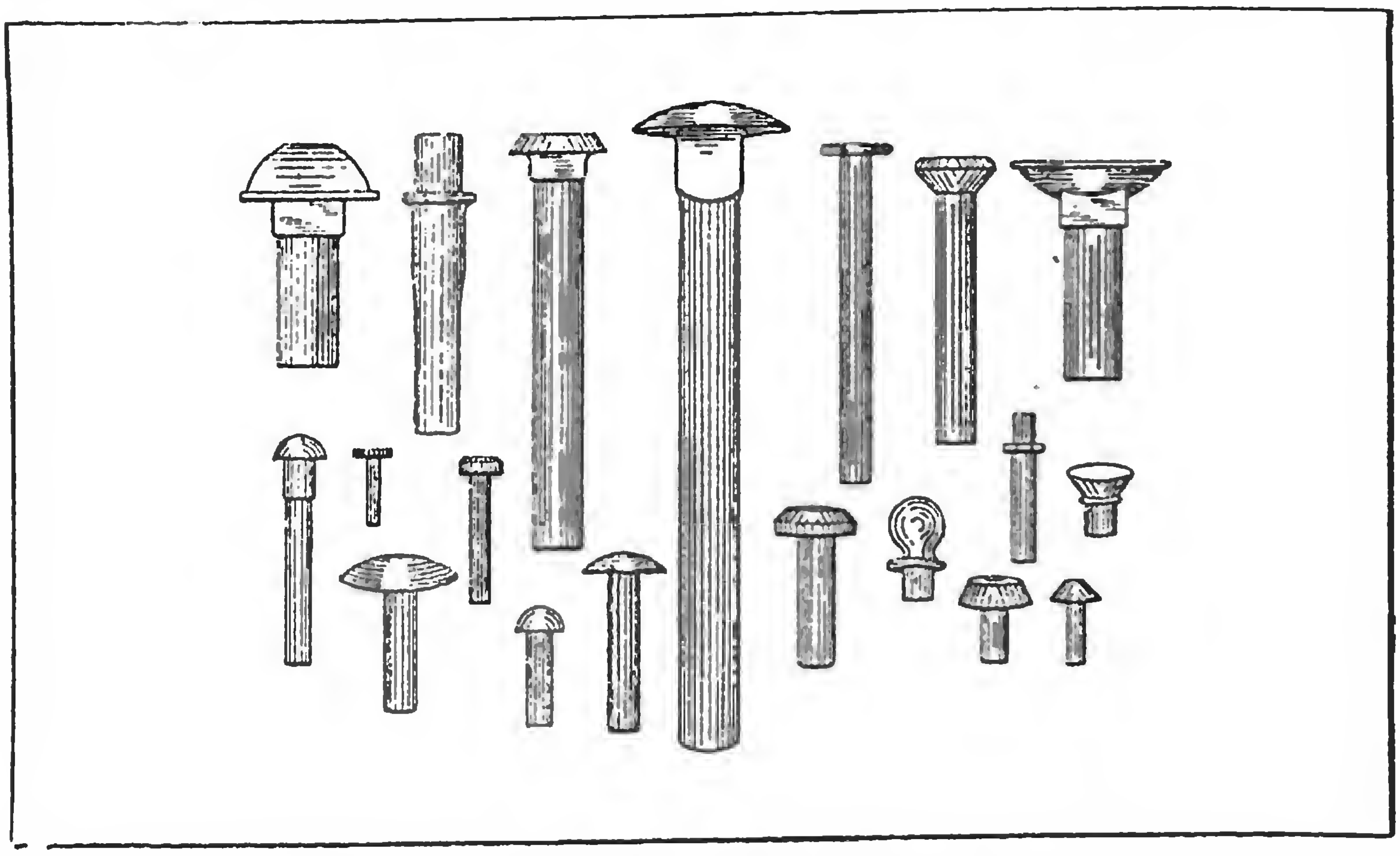


(A) Crank-header Diagram. (B) Two-cycle Toggle-header. (C) One-cycle Toggle-header.

well. On double-stroke cold-headers of the crank-operated type (see illustration *A*), the crankshaft must make two revolutions in order to secure the two strokes, and these two strokes will be of equal length. The blow secured by the crank-operated header is of a quick punching character rather than a gradual squeezing operation, and exponents of crank-operated headers consider this feature to be of great importance.

The common type of toggle action is that shown at *B;* the toggle is straightened by a crank-actuated link which brings the arms of the toggle to a straight line once during each revolution of the crankshaft. This gives one stroke of the ram to each revolution of the crankshaft, but a gradual squeezing movement is obtained, especially at the ends of the stroke where the greatest amount of work is done. This type of toggle mechanism is known as the "two-cycle" type, two revolutions of the crankshaft being necessary to complete a "two-blow" rivet. Another type of toggle-operating mechanism which is extensively used on the double-stroke machines is shown at *C;* as will be seen, two blows are struck at each revolution of the crankshaft which operates the arms of the toggle. As this type of machine makes a two-blow rivet in the revolution, it is termed a "one-cycle" machine. The chief difference between the two-cycle type of toggle and

the one-cycle type lies in the fact that in the two-cycle mechanism the toggle is straightened when the extreme of the crank motion is reached, but in the one-cycle mechanism it is straightened and then pushed beyond the central position by the crank,



Miscellaneous Examples of Cold-heading

so that in the latter machine two blows are secured during one revolution of the crankshaft.

Many heading jobs require two distinct operations to perform the work, usually on account of the shape of the pieces. For this purpose, the work is carried as far as possible with an ordinary single- or double-stroke header, after which the pieces are annealed and completed in a reheader. For handling work in which the length of the pieces under the head exceeds nine or ten diameters of the wire, it is necessary to employ dies which open longitudinally to make ejection of the work possible.

Cold-Heading. The operation of forming the heads of rivets, wood-screw blanks, machine-screw blanks, and similar products, by upsetting the ends of the wire lengths while cold, is known as *cold-heading*. The machine to which the wire is fed from a coil, and in which it is cut off and headed, are known as *cold-headers*. A general idea of the classes of work done by cold-heading may be obtained from the illustration, which shows some miscellaneous examples.

In all cold-heading operations the blank is confined at the bottom and sides, leaving the metal which is to comprise the head projecting, so that it may be upset and shaped by the punch of the heading machine. In cold-heading, the funda-

mental point to be remembered is that, under pressure, the wire stock will always flow in the direction of the least resistance. Cold-heading by machinery was first introduced in England, about 1760, when two brothers, John and William Wyatt, designed and built a machine for heading wood-screw blanks. In America, Josiah Gilbert Pierson's cold-header, patented March 23, 1794, was the first machine of its kind, although the patents were destroyed when the patent office was burned early in the last century.

Cold-Heading Dies. Punches and dies for cold-heading can usually be made from shallow-hardening steels such as the water-hardening carbon tool steels—AISI types W1, W2, W3, W4, W5, or W9—with or without chromium and vanadium, and having carbon contents varying from 0.85 to 1.10 per cent. Type M2 tool steel punches have proven to be very successful.

Carbide inserts are often practical, particularly for long die life on close-tolerance work. However, the particular type of carbide to be used must be selected carefully since carbides are available in grades from very hard (for maximum wear) to very soft (for best shock resistance). Selection charts are available from most carbide suppliers. Carbide dies should be carefully ground and lapped to less than a 4 micro-inch finish.

It is most important that the tool steel have a controllable depth of hardening since the surfaces must withstand severe impact and abrasion. The body must be tough enough to resist the high internal pressures. For solid cold-heading dies, this is accomplished by flush-quenching through the hole only; the exterior surface should not be quenched. Also, header dies having deep impressions, like solid dies, should be flush-quenched in a special fixture using controlled water pressure. This prevents gas pockets from forming on the working surface of the die during quenching. Most tool steels for cold-heading are heat-treated at a temperature of about 1500 degrees F., quenched in water, and drawn at approximately 450 degrees F. to produce a surface of hardness of 59 to 62 Rockwell C, and a body hardness of about 39 to 41 Rockwell C. Depth of case should be approximately one-eighth inch.

Solid dies are usually produced from round bar stock with the required hole bored and ground to size. Close tolerances must be held with regard to straightness of the hole and its concentricity with the outside diameter. Final finishing of the hole and/or working surfaces of the dies is accomplished by grinding, lapping or polishing. The finer and smoother the surface, the better these results obtained. The dies are usually made double-ended so that they can be reversed once worn.

Many transfer-headers use cased or sectional dies instead of solid dies when wear on the various parts of the die may be un-

even. Splitting a die into component parts that are fitted into a die case requires greater precision than die manufacturing, but it pays dividends in that selected hardness can be used where needed and maximum life obtained for various components—rather than throwing away a solid die which is only partially worn. Die components are mounted in a case with an interference fit, varying from 0.004 to 0.010 inch (depending on the diameter of the die). Lead angles of six degrees on the insert and eight degrees on the case are generally used. The casing of carbide dies and components can be more difficult because of the possibility of cracking the insert with too great a preload. Also, if the preload is too little, the internal bursting stresses on the die cause it to crack. The preload induced in the casing must exceed the working pressures of the die itself.

The grooves in open-die blocks are generally machined and ground by placing the blocks end-to-end. In grinding, about 0.003 inch of stock is ground from the flat mating surfaces below the center of the grooves to insure firm gripping of the stock. The sharp edges formed where these faces join the grooves are stoned to prevent their cutting into the stock.

Cavities in the punch, the die, or both—depending on the method of forming the head or collar—can be produced by boring and grinding, or by hubbing (sometimes called hobbing)—pressing a hardened hub (or hob) in the shape of the required head into a die blank of annealed tool steel which is then hardened.

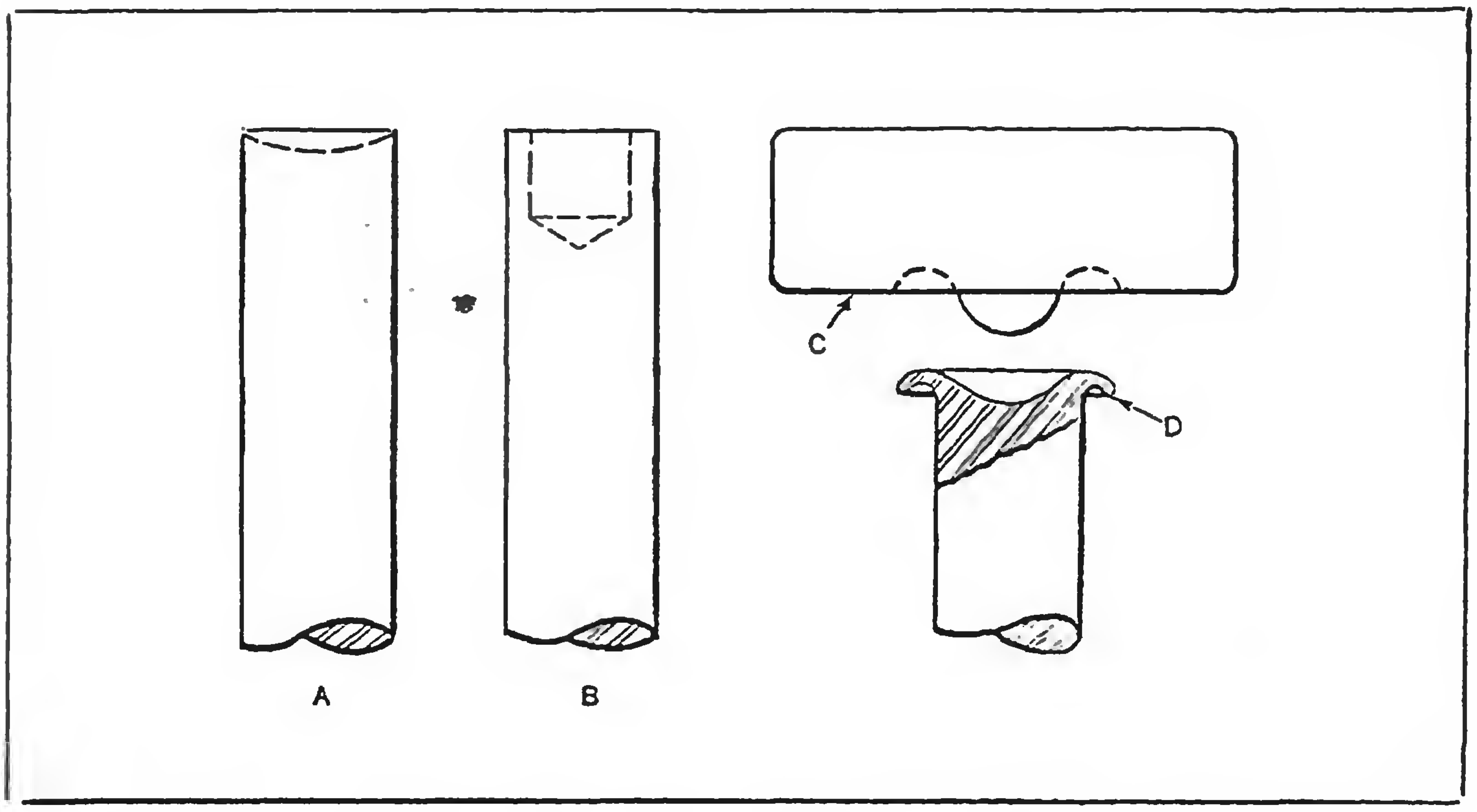
Cold-Pressed Castings. Castings of brass, bronze, aluminum and various alloys, as well as some steel and malleable castings, may be finished by a cold sizing or pressing operation in a powerful press equipped with dies shaped to suit the work. This general process may be for accurate sizing or it may be utilized in preparing some classes of hardware castings for plating, as the surface of a casting can be pressed smooth enough to eliminate or greatly reduce preparatory hand work and buffing. The pressure for such work is liable to be approximately 90 tons per square inch of projected area.

Cold-Pressed Forgings. The bosses and angular or flat surfaces, etc., on many of the smaller classes of drop forgings may be finished to size within a plus and minus tolerance of about 0.001 inch, by a cold-pressing or cold-sizing process. A powerful press such as the knuckle joint type, is used in conjunction with dies shaped to suit the shape of the boss or other part of the forging, and the working pressure may be as high as 100 tons per square inch or even higher. The object of this cold-finishing or squeezing method of sizing forgings is to

obtain accuracy of form and size quickly and without milling or grinding operations.

The usual finish allowance for work of this character is 1/32 inch and in some cases 1/16 inch. More can be allowed, but is not required. It may be pointed out that if the rough forgings vary considerably, the pressure which the press is required to exert will also vary considerably. Accordingly, if the press is not heavy and of rigid construction, it will spring in proportion to the load, giving a possible variation beyond the tolerance. It is best to figure the pressure requirement for sizing work (close tolerance, small compression, free flow) at about 60 to 80 tons per square inch of surface to be squeezed; 400-, 600-, and 800-ton capacity presses seem to have proved the most satisfactory for the general run of automobile forgings.

Cold Rivets. In the manufacture of some products, it is the practice to use "cold rivets" which, instead of having heads, are cupped out on the ends to permit upsetting sufficiently to form a small flange or head. One type of cold rivet is shown at *A* in the accompanying illustration. These rivets are made slightly concave at each end so that they may be readily headed by a pneumatic hammer. At *B* is shown a rivet with a drilled hole at each end. The holes are drilled about ¼ inch deep and of



Cold Rivet Head Formation

such diameter as to leave a wall from 1/16 to 5/32 inch thick, depending on the size of the rivet. Rivets of this design can readily be upset on both ends at one operation in a hydraulic press by equipping the upper and lower dies with hardened

steel buttons like that shown at *C*. The shape of the head after compressing is shown at *D*.

Cold-Rolled Sheet Steel. Cold-rolled steel possesses several advantages which cannot be secured with metal that is rolled hot. Most important of these is that rolling the metal cold enables it to be given a so-called "bright" finish, there being no oxide scale or stains on the surface. When the steel is rolled hot, the hot metal is easily attacked by the oxygen of the air, which results in forming the scale with which heated metal is covered. This oxide scale is hard and it exerts a very harmful effect on the dies used for working sheet metals. For this reason, cold-rolled steel is extensively used in the manufacture of various pressed steel products. The possibility of rolling steel without forming any scale has another important advantage, in that sheet metal produced in this way can be rolled very thin, the limit being about 0.003 inch; evidently this would be impossible if the metal were at a red heat, because the production of scale would cause considerable variation in the gage of the metal, and would destroy very thin sheets.

Mills engaged in the manufacture of cold-rolled steel secure their raw material in the form of ribbon stock which is considerably thicker than the cold-rolled steel to be produced. The treatment of this material in the early stages of the process differs according to the carbon content. For steel which does not contain over 0.30 per cent of carbon, it is unnecessary to conduct a preliminary annealing process, but steel with more than 0.30 per cent of carbon must be annealed before rolling. The amount of reduction which can be obtained for each pass through the rolling mills depends upon the analysis of the steel; with low-carbon steel, the reduction may be as great as 0.022 inch for each pass, and this reduction will be gradually reduced until the final pass will only reduce the thickness of the metal about 0.005 inch. In the case of high-carbon stock, the reduction at each pass through the mill is much less.

Cold-Rolling. The cold-rolling of shafting or bar stock consists in passing the shaft or bar through burnishing rolls which leave a smooth dense surface. Most shafts and bars, however, which are designated as "cold-rolled," have been finished by a cold-drawing process which involves pulling the stock through dies. See Cold-drawing.

Cold-saw Cutting-off Machines. Cold-saw machines which utilize a revolving saw are built in many different designs which differ principally in regard to the methods of driving the saw and giving it a feeding movement relative to the work. The saw

is usually mounted on an arbor, which is rotated either through spur gearing, worm gearing, a combination of spur and worm gearing, or by the direct action of a sprocket engaging either the saw teeth or radial slots formed in the saw. A general method of feeding the saw is by means of a carriage or saddle which carries the saw and its driving mechanism, and is moved along the bed by a feed-screw. Some machines are so arranged that the saw is given a swinging movement for feeding it, by mounting the saw upon an arm which is pivoted and connected with suitable feeding mechanism, which may be in the form of worm gearing, a pinion meshing with a segment gear on the arm, or a gear-driven screw connected with the arm.

Duplex Cold Saw: The Duplex type of cold saw consists of two machines mounted upon the same bed so that the distance between the saws may be varied. Machines of this type are used for cutting off the ends of axles, crankshafts, etc., to given lengths, and also for sawing crankshafts in order to form the crank or web from a solid forging.

Multiple Cold Saw: The multiple cold saw cutting-off machine is used for cutting long bars into a number of short lengths. One machine of this type is equipped with six heads each having a saw which operates independently. The saws feed forward and return automatically. These machines are usually designed and built to suit special classes of work.

Cold Saw of Vertical Type: Some cutting-off machines have a vertical spindle and a saw which revolves in a horizontal plane. One design which is especially adapted for cutting off gates and risers from cast-steel gears, and other similar work, has a circular work table which is arranged very much like the table of an ordinary slotting machine. Another type of cold saw which is designed along vertical lines has a vertical column on the face of which is a saddle carrying a horizontal saw arbor, the saw in this case being in a vertical plane. The vertical column may be fed horizontally along the main base of the machine and the saddle may also be given a vertical feeding movement on the face of the column. A machine of this type is especially adapted for sawing armor plate.

Cold Shuts. A cold shut is caused by the imperfect uniting of two or more streams of molten iron flowing together, which are too cold to coalesce. Such a fault often occurs on the upper side of a thin cylinder cast horizontally, when the iron is not sufficiently hot at the instant of pouring. It appears as a seam in the side of the cylinder, and it is very apparent that the metal has united imperfectly. Such a defect will cause the casting to split if subjected to any great stress, and it will leak under

pressure. This imperfection is generally due to thinness of the metal or to improper gating. If the iron flows in thin streams for comparatively long distances, it will be cooled very much, and probably the advancing face will be partially solidified.

Cold Test of Oil. The cold test of an oil is to determine the lowest temperature at which the oil will pour. A low cold test is desirable in cold weather to insure proper circulation and handling; furthermore, a low cold test for motor oils indicates the absence of heavy elements that produce carbon in the cylinders. The effect of decrease in temperature upon lubricating oils is not the same as on fluids such as water, glycerin, etc., which have fixed freezing points. Lubricating oils, which contain elements having different melting points, often deposit some of these elements before the entire mixture solidifies; consequently, the "cold test" or setting point of an oil may represent the temperature at which the solid matter begins to separate, or it may be the temperature at which the oil loses its fluidity. The setting point of a Scotch mineral oil is the temperature at which the solid paraffin begins to separate. Some pale American oils of high viscosity, Russian oils, and all dark opaque oils, which either deposit no paraffin or in which the separation cannot be seen, are considered to have reached the setting point when they cease to flow.

Cold-Twisting. Cold-twisting is the term applied to a process for producing bars for reinforced concrete construction. The cold-twisting increases the elastic limit and produces a bar which has a more intimate bond with the concrete and greater reinforcing effect.

Cold-Upsetting. See Cold Heading.

Cold-Working. Cold-working can be defined as plastic deformation of metals below their recrystallization temperatures, as the result of which strain- or work-hardening occurs. The recrystallization temperatures for cold-worked steels vary from 950 to 1300 degrees F., depending on the rate and amount of deformation.

Coleco Metal. The bearing metal known as *coleco metal* is a lead-tin-antimony alloy, also containing a small percentage of copper. One composition specifies 77 per cent of lead, 14 per cent of antimony, 8 per cent of tin, and 1 per cent of copper.

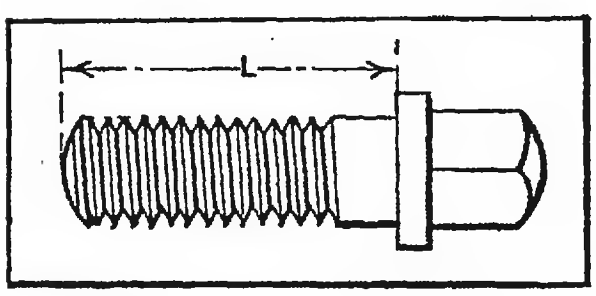
Collapsible Taps. See Taps, Collapsible.

Collapsible Tubes. Collapsible tubes, such as are commonly used for artists' colors, tooth paste, etc., are usually manufactured by the cold extrusion process. The metal from which

these tubes are made is of either tin or lead composition and there is a large variety of alloys suitable for this class of work. These tubes are also often made from pure tin, and such tubes are considered superior to those made from the various compositions. The tubes are extruded from blanks of disk or special shapes.

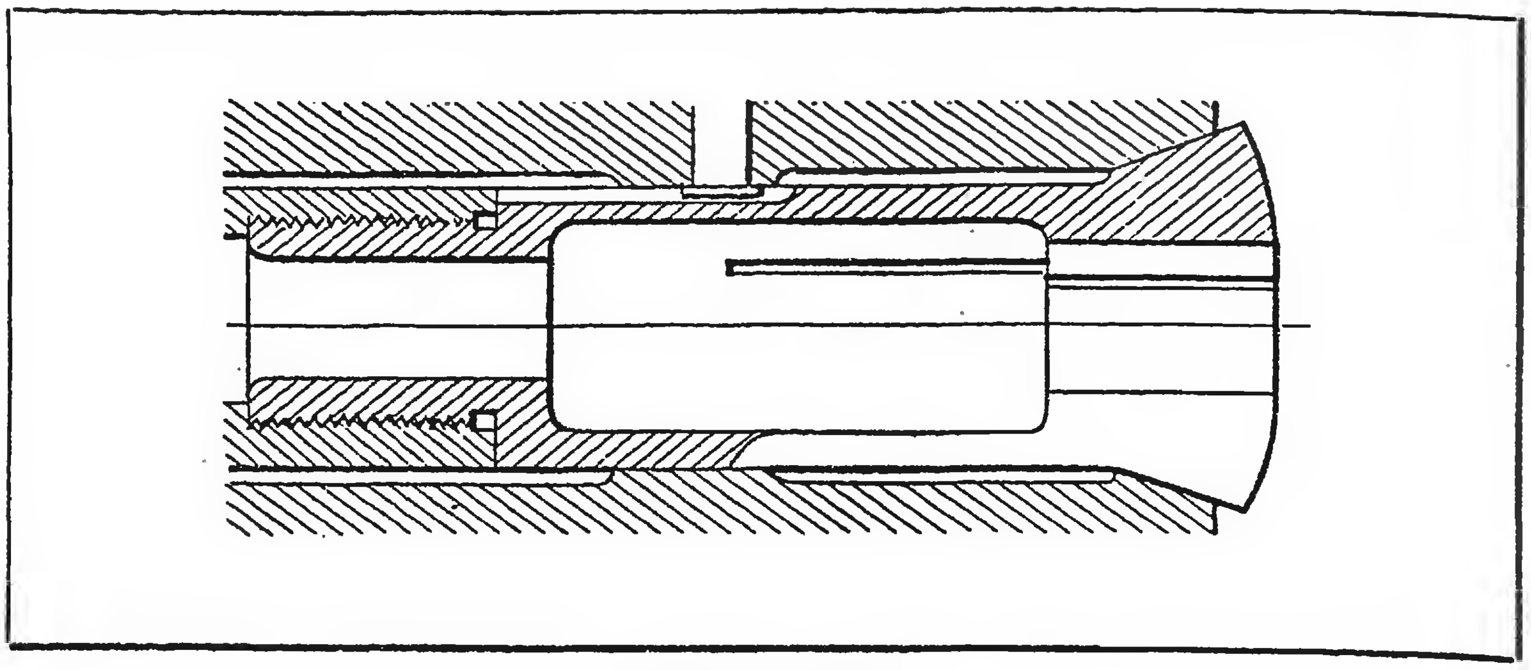
An alloy which will be found suitable for both collapsible tubes and soft metal bottle tops, consists of 4 ounces copper, 6 ounces antimony and 16 ounces tin, melted together, the resulting alloy being used with varying quantities of pig tin. For collapsible tubes 50 ounces of the alloy and 200 pounds of pig tin are used; for bottle tops, 134 ounces of the alloy and 200 pounds of pig tin. Any one of the three following compositions may also be used successfully in the manufacture of collapsible tubes: (1) antimony 14 per cent and tin 86 per cent; (2) antimony 5 per cent and tin 95 per cent; (3) copper 2 per cent and tin 98 per cent. Collapsible tubes are now being produced successfully from aluminum. The annealing process for restoring the ductility of the metal after extrusion is an important part of this development.

Collar-Head Screws. Collar-head screws are used on finished work, or on rough work which has been spot-faced to provide a bearing for the collar or enlarged part of the head. Screws of the collar-head form are also commonly used in toolposts or tool-holders of various kinds; the particular advantage is that the collar prevents a wrench from slipping down below the head, thus causing inconvenience in making adjustments. Dimension *L* (see illustration) represents the nominal length of the screw.



Collar-head Screw

Collet Chuck. The collet type of chuck consists of a split sleeve or collet which has a tapering or conical end that fits into a seat of corresponding taper so that a lengthwise movement of the collet causes a contraction or expansion of the gripping surfaces (see illustration). The collet type of chuck is the most convenient form for gripping pieces that are long in relation to their diameter, such as bar stock, etc. Collet chucks are extensively used on bench lathes, turret lathes (when operating on bar stock), and on turning machines of the automatic screw machine class.



Collet Chuck

Some collet chucks are closed by a backward pull and others by a forward push, the movement for closing depending upon the inclination of the taper.

Colloidal Fuel. A mixture of fuel oil and pure coal is known as colloidal fuel. The usual amount of coal is about 40 per cent by weight, with possibly 1 per cent of some emulsifying agent. The oil may have suspended in it, however, as much as 65 per cent of coal by weight and yet be sufficiently fluid to permit pumping or atomization. The object is to combine with the oil low-grade coals of the high fixed carbon or high ash types which cannot be burned successfully in the usual manner. Colloidal fuel has a heating value per pound varying from 14,500 to 17,000 British thermal units, a weight of 8.3 to 11 pounds per gallon, and for equal volumes it has nearly twice the power value of coal, and nearly 10 per cent more than fuel oil. It can be covered with water and sinks in water, thus reducing the fire hazard.

Cologarithms. The cologarithm of a number is the logarithm of the reciprocal of that number. "Cologs" haye no properties different from those of ordinary logarithms but they enable division to be carried out by addition because the addition of a colog is the same as the subtraction of a logarithm.

Coloring Metals. See kind of metal or finish: Brass Coloring; Copper Coloring; Cyanide Coloring of Steel; Flemish Finish on Brass; Heat-black Finish; Silver Finish on Brass; Steel Coloring.

Coloring Polished Parts. The term "coloring," as used in the metal finishing trade in connection with polishing or buffing, refers to the operation whereby a very fine finish is obtained.

Chisels, hammers, screwdrivers, wrenches, and similar classes of work which are to be highly finished, but not plated, usually require four operations which are: roughing, dry-fining, greasing and coloring. That is, by means of four operations all the finishing work is done on polishing wheels, including the roughing which is frequently regarded as a solid grinding wheel job. Sometimes there are two steps to the greasing operation—rough and fine greasing. For some hardware, typical of which are cheaper screwdrivers and wrenches that do not demand a high finish, two operations are sufficient—roughing and dry-fining. The coloring operation may follow plating in order to give the plated surfaces a luster.

Columbium. A metallic element of steel gray color and having a bright metallic luster, also known as *niobium.* Its chemical symbol is either Cb or Nb; atomic weight, 93.5; specific gravity about 7; and melting point 2200 degrees C. (about 4000 degrees F.). Iron containing 3 per cent columbium has been found to have exceptionally good rupture strength at temperatures as high as 1100 degrees F., indicating potential applications in high-temperature steam turbine construction. By itself the element is malleable and ductile, and highly resistant to corrosion. At one time it was used in lamp filaments, and is now used in jewelry. There is also a columbium-stabilized 18-8 (stainless) steel in which the columbium forms a carbide. The element does not occur in the free state, and its minerals are relatively rare. Only a small tonnage is produced annually and this comes chiefly from Australia. The element was discovered in 1801 in America and hence was named columbium.

Column. In engineering, a column is a structural member which has considerable length in proportion to its width, depth, or diameter, so that failure in compression is most likely to occur by the effect of bending stresses rather than by crushing. Generally, a structural member subjected to compression is known as a column, strut, or post if its length exceeds from six to ten times its width, depth, or diameter.

Column Formulas. See Rankine's Formulas.

Combination Chucks. The combination type of chuck is so arranged that the jaws may be adjusted either independently or universally. There are two common methods of obtaining this change of adjustment. In the design having geared screws operated by a circular rack or gear, the latter is so arranged that it may be dropped out of mesh with the screw pinions, so that each screw may be turned independently. With a scroll type of combination chuck, all of the jaws may be moved together by rotat-

ing a spiral scroll or they may be adjusted independently by turning screws that are located between the jaws and the scroll.

Combination Grinding Wheel. When a wheel is made up of abrasive grains of different sizes or numbers, it is known as a combination wheel. The coarser grains are effective in taking roughing cuts, but the wheel is sufficiently compact to obtain a fine finish if properly used. Such wheels are extensively employed.

Combined Carbon. This is the form in which carbon is present in white cast iron, the carbon being in chemical combination with iron as cementite or carbide of iron, (Fe_3C). The combined carbon is the principal factor in determining the hardness, strength, and soundness of castings.

Combustion. Chemically considered, combustion is the chemical union of oxygen with other elements and compounds at a rapid rate—usually so rapid that heat and flame are produced. When combustion is extremely rapid, it is termed an "explosion."

The combustion of a fuel requires three stages: 1. The absorption of heat to raise its temperature to the point of ignition. 2. The distillation and burning of the volatile gases. 3. The combustion of the fixed carbon. When fresh fuel is added to the fire, it absorbs heat until its temperature reaches the point at which the combustible elements will unite with the oxygen of the air. This point varies with the kind of fuel, commonly running from 600 to 800 degrees F. in the case of lump coal and coke. Carbon monoxide requires a temperature of 1210 degrees F., and hydrogen, 1100 degrees F. While the coal is being raised to the point of ignition, the so-called "hydrocarbons," such as marsh gas, tar, pitch, naphtha, etc., are driven off in the form of a gas and combine with the oxygen of the air which is supplied through the bed of the hot fuel. When the hydrocarbons have been driven off, combustion of the solid portion of the fuel, that is, the carbon, takes place. This unites with the oxygen of the air to form carbon monoxide and carbon dioxide. Any substances which are not combustible remain in the form of ash and clinker.

Air Required for Combustion: The theoretical amount of air required for the combustion of various fuels, in pounds per pound of fuel, based on typical analyses of each is as follows: Coke, 10.8; anthracite, 11.7; bituminous coal, 11.6; lignite, 8.9; wood, 6.0; and oil, 14.3. In practice, due to the impurities in fuel and the difficulty in getting air into contact with all particles, it is impossible to obtain perfect combustion with the theoretical amount of air, and an excess sometimes equal to

double the theoretical amount is required. Usually, however, about 50 per cent excess air is sufficient to meet the requirements. This excess air is required because ideal conditions for combustion cannot be attained in actual practice, owing to the difficulty in supplying air to all parts of the fire uniformly. This results in some of the fuel receiving less oxygen than is necessary for complete combustion, while other parts have a surplus. On the other hand, if too much air is supplied and insufficient time is allowed after the gases have become incandescent, before they come in contact with the cooler plates of the boiler, combustion will also be retarded.

Combustion Elements in Fuels. The elements contained in the usual forms of fuel, which enter into the process of combustion, are oxygen, carbon, hydrogen, and sulphur. There are various other constituents present which have no fuel value, such as the iron, silicon, etc., found in coal. These usually exist in small quantities, and are classed as impurities. They produce a certain waste in the form of ash, and, in addition to this, their temperature must be raised to that of the fire before becoming separated from the other elements, and more or less of this heat is lost as they are discharged from the fire.

Oxygen is the universal element of combustion; it is an invisible gas and makes up about one-fifth the volume of the air in an uncombined state. It is usually present in coal in amounts varying from 1 to 25 per cent, according to the grade. *Carbon* is a solid, and is found in a pure state in the form of graphite and charcoal. It is the principal heat-producing element in coal and other fuels, including liquids and gases. *Hydrogen* is a combustible gas, and exists in nature only in combination with some other element.

Nitrogen is an invisible gas, forming about four-fifths the volume of the atmosphere. It does not unite chemically with the other constituents of the air or take any part in the process of combustion. For this reason it is a source of loss in the operation of a steam boiler, because, in order to supply the necessary oxygen for combustion, four times the volume of nitrogen must be raised from the temperature of the atmosphere to the point of combustion, and then discharged at a high temperature with the waste gases into the chimney. This process adds nothing to the heat of the furnace and is constantly extracting heat from it. Nitrogen is found in coal in amounts varying from 0.5 to 2 per cent, by weight. *Sulphur* enters into the composition of coal in amounts varying from 0.5 to 5 per cent. Although sulphur is combustible, the amount of heat given off is small, and the

gases are so detrimental to the boiler plates that it is commonly considered an impurity.

Combustion of Coal. Combustion of coal involves the rapid chemical union of oxygen with carbon, hydrogen, and sulphur (and other elements) accompanied by a diffusion of heat and light. Perfect combustion occurs when the combustible unites with the greatest possible amount of oxygen, but without excess. Imperfect combustion occurs when the union between the combustible and oxygen is incomplete, or when an excess of oxygen is present. The principal combustibles in fuels are carbon, hydrogen, and sulphur. Carbon is the most abundant. Hydrogen is usually found in combination with carbon in the form of hydrocarbons. Sulphur is found in most coals. It usually occurs either as a sulphite of iron or a sulphate of lime.

Each combustible element will unite with oxygen in certain definite proportions and will generate a definite amount of heat which is termed the *calorific value* of the substance. Some calorific values of elementary combustion are given below. Carbon to carbon dioxide, 14,600 B.T.U.; carbon to carbon monoxide. 4450 B.T.U.; carbon monoxide to carbon dioxide, 10,150 B.T.U.; hydrogen to water, 62,000 B.T.U.; methane CH_4 to carbon dioxide and water, 23,550 B.T.U.; sulphur to sulphur dioxide, 4050 B.T.U. Thus, when one pound of carbon is burned to carbon dioxide, sufficient heat is generated to raise 14,600 pounds of water one degree, or one-half of this amount of water two degrees.

Combustion, Spontaneous. See Spontaneous Combustion.

Combustion, Surface. See Surface Combustion.

Commutating Poles. Small narrow poles placed between the main poles of direct-current machines for preventing sparking between one of the edges of the brushes and the commutator. The commutating poles are wound in series with the armature winding and this exciting winding carries a current proportional to the load current and produces a flux in such a direction and phase as to assist the reversal of the current in the short circuited coil.

Commutation. The currents flowing in the armature coils of a direct current generator are reversed in direction as each coil segment passes from the field of one magnetic pole into the field of one of the opposite polarity. A direct current can, however, be made to flow through the generator terminals if provision is made for reversing the connections from each coil to the external circuit as the direction of the electromotive force induced in the coil reverses. This is accomplished by the proper

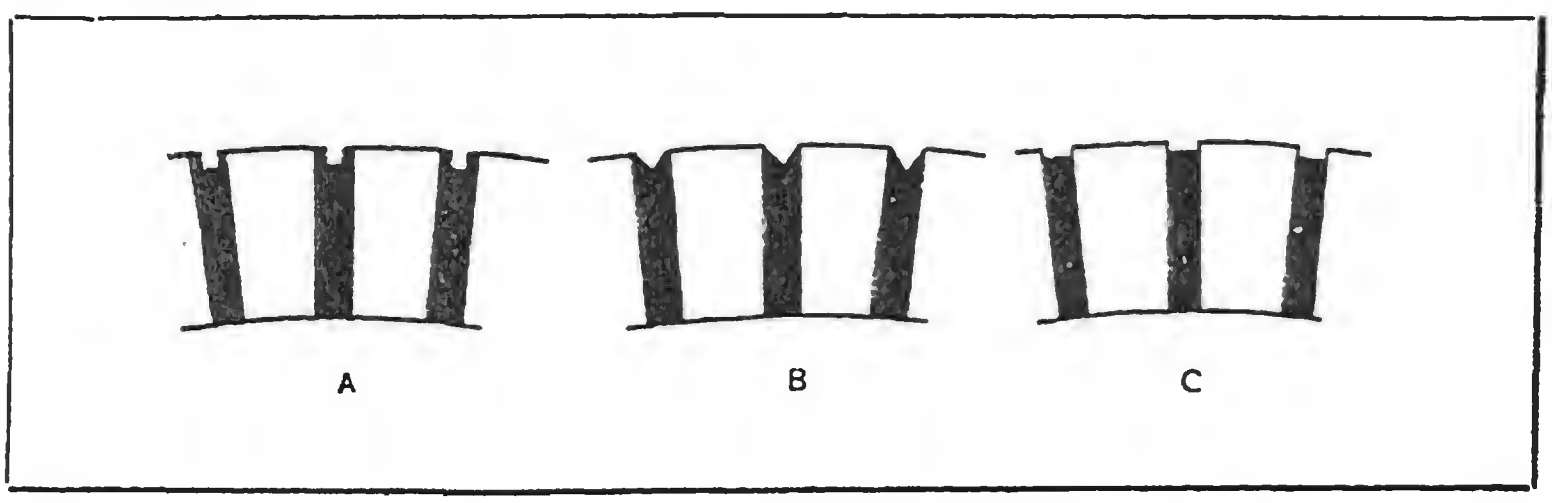
spacing of armature coils and their connections to the individual segments of the commutator so that contact with the brushes is made at the proper moment with respect to the position of the coils in the magnetic pole fields. When the connections to an armature coil are so reversed, the coil is said to undergo *commutation.*

In the case of a direct current motor, since direct current is supplied to its terminals, commutation is provided to change the direction of current flowing in each coil as it passes from one magnetic field to another of the opposite polarity so that continuous torque in the same direction may be applied to the armature.

Commutator. See Armature, Motor; also Generators, Direct-current.

Commutator Controller. A hand-operated electric motor controller of the non-automatic type used as a reversing controller. It is similar in construction to the drum controller, except that in the commutator controller the fingers revolve instead of the drum. This controller is limited in size to approximately from 100 to 150 horsepower, but is mechanically strong and simple to operate and can be provided with brushes that make it very durable in heavy service.

Commutator Insulation. The mica insulation between the copper commutator segments is usually more resistant to the wear of the brushes than the segments. This results in the copper wearing off and leaving the mica projecting, a condition termed "high mica." Pure amber mica, which has about the same wearing qualities as the copper used in commutator segments, was formerly used, but it is very expensive and difficult to obtain. The mica used consists of built-up sheets made from plates or lamellae 0.002 to 0.004 inch thick of both amber mica and the harder, white kind of mica stuck together with some gum or resin. Both the white mica and the baked binder are harder and more resistant to wear than the copper commutator segments.



Commutator Mica Insulation

In order to prevent the "high mica" condition, the mica is generally grooved or under-cut between the segments as shown at *A*, and *B*. The style of under-cut as shown at *A* has been considered the better, although its superiority, if any, is not pronounced. The condition shown at *C* should be avoided, especially in the case of large, slow-speed machines, or machines operating in places where dust of a current-conducting nature is prevalent. The entire brush contact area should be grooved without having the grooves run out on the end of the commutator. Ordinarily, the grooves should be about 1/32 inch deep.

Commutator Motors, Alternating Current. There are two main types of alternating-current motors with commutator-connected windings: series motors and repulsion motors.

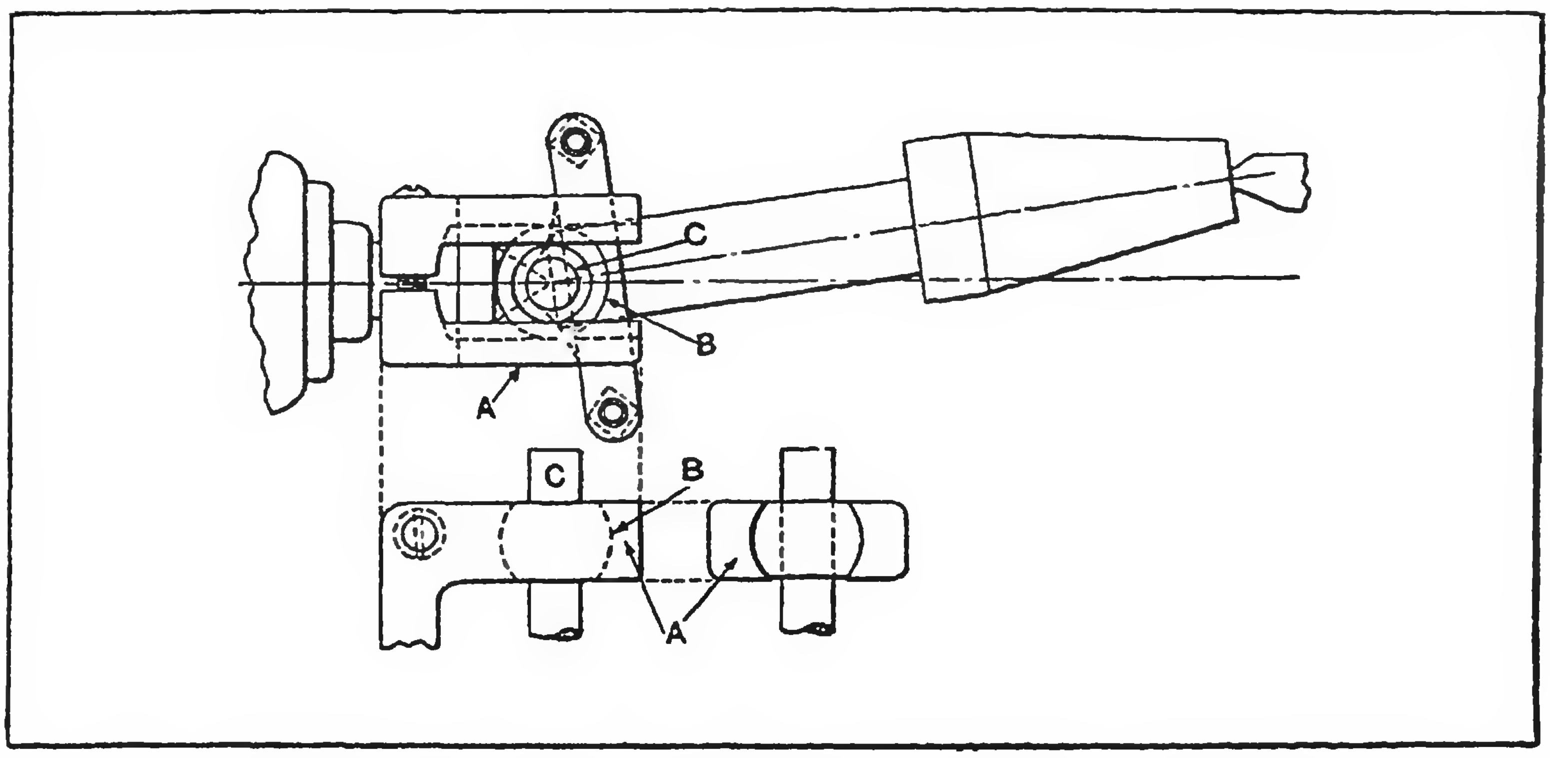
Alternating-current series motors are much like direct-current series motors in their characteristics. Their construction is different, however, in that they have laminated field structures instead of a cast structure to prevent excess eddy-currents and only a few turns in the field coils to avoid low power factor from high inductance. They are widely used in low power applications requiring motors of from 1/100 to 1/3 horsepower, and in these sizes are often termed *universal* as they may also be operated on direct current. They are called series motors because the stator and rotor windings are connected in series.

Repulsion motors are equipped with a commutator-connected winding which provides a high starting torque. In the *repulsion-start induction* motor, this winding is cut out, after the machine reaches a certain per cent of synchronous speed, by the short-circuiting or lifting of the brushes from the commutator. The motor then runs as a straight induction motor on a squirrel-cage winding.

In the *repulsion induction motor,* the brushes are not disconnected and part of the current merely shifts from the repulsion winding to the squirrel-cage winding as the motor comes up to speed.

Also using a commutator, is a polyphase adjustable-speed motor which has two sets of brushes that are shifted for speed control.

Compensating Dog. A compensating dog or driver is a type designed to prevent the inaccuracy in spacing which often results when indexing taper work. If the axis of the work is not in alignment with the axis of the dividing-head spindle, and an ordinary driver is used, the spaces will vary somewhat, especially if the work is held at a considerable angle. A form of compensating driver which practically eliminates this error has



Compensating Dog to Eliminate Indexing Errors

a forked arm *A* (see illustration) which is secured to the dividing-head spindle. This arm is engaged by a ball-shaped part *B* mounted on the cylindrical end *C* of the driver. The latter is clamped in such a position that the center of the cylindrical driving end is approximately in line with the end of the work, as shown by the plan view. The ball fits closely between the curved surfaces of the forked arm and adjusts itself as the relation between the driver and arm change owing to the angularity between the axes of the work and the index spindle. The forked arm can be adjusted to take up all play between the ball and the curved surfaces between which the ball is held. As the driving is done at a point opposite the end of the work, the irregularity of the indexing movement is very slight and negligible for ordinary milling or fluting operations; moreover, there is no binding action between the dog and driver plate, such as may occur with the ordinary dog, having a tapering driving end.

Compensators. Compensators for line drop are devices used to modify the reading of electric power station voltmeters, without the use of pressure wire from the distributing point, so that the reading corresponds to the pressure at that point. *Balances* are sometimes called compensators or direct-current compensators.

Complement of Angle. The complement of a given angle (a) equals $90° - a$; hence if the angle a exceeds 90 degrees, its complement is negative. The complement angle of a 60-degree angle equals $90 - 60 = 30$ degrees.

Composite Gear Tooth System. See Gear Tooth Standard, American.

Composition of Forces. The expression "composition of forces" relates to the finding of the resultant of two or more forces. See Force.

Compound. In chemistry, a compound is a substance consisting of chemically united atoms of two or more elements. For example, sulphuric acid which consists of hydrogen, sulphur, and oxygen is a chemical compound. Substances which can be decomposed into simpler ones are known as compounds; those which cannot be decomposed into anything simpler are known as *elements.*

A substance is a mechanical mixture or a chemical compound, according as the elements composing it lose or retain their identity. If chlorine and hydrogen are mixed in any proportion, the chlorine in the mixture may be evident by its characteristic color and odor, showing that the combination is only a mechanical mixture. If, however, this mixture is exposed to a strong light, a new compound is formed in which the chlorine cannot be detected either by any odor or color, nor can it be separated except by chemical means; this combination, known as hydrochloric acid, is a chemical compound. The gases, however, will combine only in exactly equal volumes, so that if there is any excess of either element present that part will remain uncombined. This fact is true in all cases, as a chemical compound differs from a mechanical mixture in that each element of the chemical compound has a certain fixed and unvariable combining proportion, which is its valence; whereas, a mechanical mixture of substances can be made with varying amounts of each ingredient. In a mechanical mixture, the particles of each ingredient can usually be identified and separated by mechanical means, but, in a chemical combination, each component is so blended that its identity is lost.

Compound Dies. Compound dies differ from plain blanking and follow dies in that the simple punch and die elements are not separated but are combined so that both the upper and lower members contain what corresponds to a punch and die, as well as suitable stripper plates or ejectors. The faces of the punches, dies, and stripper plates are normally held at about the same level and the strippers are spring supported so as to recede when the stock is being cut. A compound die produces more accurate work than the types previously referred to for the reason that all operations are carried out simultaneously at one stroke, while the stock is firmly held between the spring-supported stripper plates and opposing die-faces. Such delicate parts as armed wheels or gear punchings for clocks, meters, etc., are examples of the work that can be done in this form of die.

Such parts are made complete, including the arm spaces, center-hole, and holes in the arms or rim, if desired, during one stroke of the press.

Compound Indexing. See Indexing.

Compound Levers. It is sometimes necessary to use two or more levers connected one to the other in a series, where it would not be convenient to obtain the desired multiplication with a single lever, or where it is necessary to distribute the forces acting. In such cases, the levers are called *compound* levers, and their application is found in testing machines, car brakes, printing presses, and especially in weighing scales.

Compound Rest. The compound rest of a lathe consists of an upper slide mounted on the lower or main cross-slide. The upper slide can be turned to any angular position so that the tool, which ordinarily is moved either lengthwise or crosswise of the bed, can be moved at an angle. The base of the compound rest is graduated in degrees and the position of these graduations shows to what angle the upper slide is set. It is also known as a Compound Slide.

Compound Stresses. Stresses acting in two or three directions at the same time are called "compound stresses." An example is found in a long thin cylinder closed at each end and subjected to internal fluid pressure. There is a tangential stress which tends to burst the cylinder along a line parallel with the axis, as well as a longitudinal stress, due to pressure on the heads, which tends to tear the cylinder apart in a plane perpendicular to the axis; that is, a small square in the wall of the cylinder is subjected to stress in two directions, each at right angles to the other. Similar examples are found in stresses due to combined bending and twisting in a shaft, stresses due to centrifugal force in a rotating wheel disk, and stresses in a hub pressed on a shaft. See Guest's Formula.

Compound Tolerances. A compound tolerance refers to those conditions where the established tolerances on more than one dimension determine the required limits. These exist in conjunction with the dimensioning of composite surfaces or those surfaces which are required to maintain a co-relation which cannot be expressed by a single dimension.

Compound-Wound Generator. This is a type of direct-current generator which is provided with both a series and a shunt field (see diagram) in order to keep the voltage constant as the

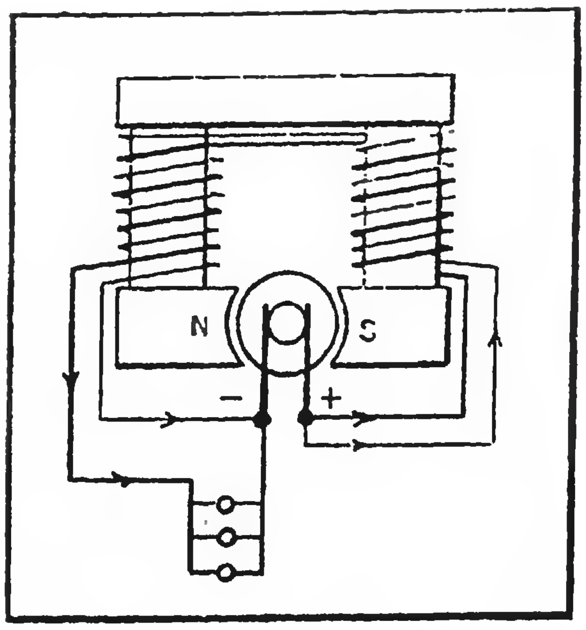


Diagram of
Compound-wound
Generator

load increases. The series winding automatically increases the excitation, and thus the voltage, as the load comes on, so as to counterbalance the drop in voltage that would take place, if only a shunt winding were provided. The series coils, therefore, reinforce the shunt field in direct proportion to the increase of load and thus hold the terminal voltage constant, balancing the drop due to increased copper loss and armature reaction at the increased load. To obtain a perfect regulation, it is also customary to provide an adjustable resistance in the shunt-field circuit similar to the simple shunt-wound generator. Compound-wound generators may be so proportioned that the voltage may be held constant over a wide range in load, and are then said to be "flat-compounded." They may also be so proportioned that the series field adds enough excitation not only to maintain a constant terminal voltage, but to increase the same as the load increases, and thus compensate for the voltage drop in the supply circuit and maintain an approximately constant voltage at the point of utilization. When so designed, the generator is said to be "over-compounded."

Compound-Wound Motor. The compound-wound motor is a direct-current motor having both a shunt and a series field winding. The shunt field is connected to the main line as in a shunt motor, while the series field is in series with the armature and carries all of the current passing through it as in the series motor. The field of an average compound motor is composed of about eighty per cent of shunt winding and twenty per cent of series winding, although this proportion may be varied to suit the class of work for which the motor is to be used. The speed of a compound motor is more nearly constant than that of a series motor, but the drop in speed from no load to full load is considerably more than in a shunt motor, owing to the action of the series part of the winding. The characteristics of the compound motor partake of those of both the series and the shunt motors in about the same degree as the relative proportion of the two windings composing the field. See Series Wound Motor and Shunt Wound Motor.

Compressed Air Intercoolers. See Intercoolers for Compressed Air.

Compressed Air, Moisture in. The atmosphere contains a certain amount of moisture or water vapor, and its capacity for moisture increases with the temperature. When compressed, this water vapor is carried with the air through the pipes to places where the air is to be used, and, as the air is often cooled considerably during its passage through long pipe lines, the water vapor has a tendency to condense. This water due to condensation frequently causes trouble. Moisture or water cannot be entirely eliminated from service lines, but much of it may be deposited by proper cooling devices. Moisture enters the compressor in the free air and passes into the intercooler, where some of it is deposited by the sudden temperature drop there. In some machines, this deposited water is drained off, but, in others, it passes with the air into the high-pressure cylinder, and the heat of compression readily absorbs it again, passing it directly to the reservoirs. If an aftercooler (this is a nest of cold tubes of a construction exactly similar to that of the intercooler) is placed between the discharge pipe of the high-pressure cylinder and the reservoir or service lines, the temperature of the air will be suddenly reduced to normal, and most of the water will be deposited where it can be drained off easily. The idea is to insure the reduction of the temperature of the discharged air to normal before it enters the service pipes. Another way is to connect at least three reservoirs in series so that the air has to pass through all of them before entering the lines. This will collect the water very well, but it is necessary to drain the reservoirs frequently. See also Air Compression and allied subjects.

Compression. Compression in a steam engine acts in connection with the premature release in order to reduce the shock at the end of the stroke. During the forward stroke of an engine, the exhaust port in front of the piston remains open. Shortly before the end of the stroke, this closes, leaving a certain amount of steam in the cylinder. The continuation of the stroke compresses this steam, and by raising its pressure forms a cushion, which, in connection with the removal of the pressure back of the piston by release, brings the piston to a stop and causes it to reverse its direction without shock. High-speed engines require a greater amount of compression than those running at low speed.

Compression, Adiabatic. See Adiabatic Expansion and Compression.

Compression Coupling. A coupling provided with a split sleeve and two conical sleeves surrounding it. The sleeves are so arranged that when the two conical outside sleeves are drawn together by bolts and nuts, the inside split sleeve grips the two shafts to be coupled together and holds them firmly.

Compression, Isothermal. See Isothermal Expansion and Compression.

Compressometer. A compressometer is an instrument which is used to determine the elastic limit of a material under compression or the deformation under fixed increments of load. It is equipped with a micrometer indicating device.

Compress Polishing Wheel. The compress polishing wheel is a type of wheel in which the material, usually leather or canvas, is placed crosswise of the face of the wheel instead of the wheel being made up of parallel flat disks. The wheel consists of an angular ring, made up of rectangular pieces of material arranged radially and compressed to form a ring or "cushion" of polishing material one or more inches in depth. This cushion is assembled with side plates engaging annular recesses in the compressed ring. The side plates, in turn, are riveted to a hub.

Computer. A computer is a device used for making mathematical computations or calculations. Computers may be broken down into two broad classifications, namely analog computers and digital computers. Analog computers are much faster, giving the answer almost instantaneously but with less precision than the digital computer. In the analog computer, numbers are represented by continuously variable quantities such as voltages, lengths or rotating shafts. In the digital computer, numbers are represented by elements such as transistors, electronic tubes, relays, and cog wheels that are capable of assuming distinct countable states. Slide rules and planimeters are examples of simple analog computers, and the abacus and desk adding machine are examples of digital computers.

Concatenation. A method of speed control sometimes called cascade control obtained by connecting alternating-current induction motors mounted on the same shaft. The primary of one motor is connected to the line while its secondary is connected to the primary of the other, and either motor may be provided with one or more windings, so as to change the number of poles. The secondary of the second motor is connected to a resistance which is eventually short-circuited. The operating speed corresponds to the sum of the number of poles on both motors and may be one-half, one-quarter, etc., the speed of either motor when running alone. The efficiency at these speeds is higher with this method than with the rheostatic method of control.

Concrete. Concrete consists of a mixture of sand, gravel, or broken stone and cement in various proportions. Water is added to this, which, when chemically combined with the cement, binds the whole mixture together into a solid mass having the char-

acteristics of strong artificial stone. In proportioning the quantities of the various materials used, the object is to obtain a concrete in which the air spaces are as small as possible, and as the cement is by far the most expensive of the materials used, it is desirable to use as little of it as is consistent with strength. The amount of each ingredient is usually measured by volume, and the mixture is generally designated by stating the proportion of each ingredient in a given order, as "1 : 2 : 5," where the first figure indicates the proportion, by volume, of cement; the second, the proportion of sand; and the third, the proportion of stone or gravel; hence, 1 : 2 : 5 concrete is a concrete containing one barrel of cement, two barrels of coarse sand, and five barrels of gravel or broken stone.

Frozen Concrete: The freezing of concrete will not damage it, if it has first had a chance to set under favorable conditions for about two days. The effect of the freezing is simply to delay the process of hardening, which will again proceed under suitable conditions, and the concrete will eventually attain its full strength. If concrete is frozen before it has commenced to set firmly, it will not be injured, provided precautions are taken to prevent it from freezing again after it thaws until it is sufficiently hardened to withstand the effects of subsequent freezings. It is alternate freezing and thawing while setting that causes the damage. When concrete work is done in winter, it is necessary to devise means of mixing the concrete with materials freed of frost, placing it in the forms before it has commenced to freeze, and then protecting it and keeping it warm for about two days.

Concrete Mixing. In making concrete, the amount of mixing water controls the strength to such an extent that strength may be predetermined simply by regulating the amount of water relative to the quantity of cement. This predetermination of concrete strengths through the use of varying amounts of water is known as the "water ratio" method. This method insures uniform strength, regardless of changes in workability or in the sizes of the aggregates. For ordinary work, the proper amount of water to use is the smallest quantity that will give a mixture of good workability. Builders in general should use as dry a mixture as practicable.

Thorough mixing is another important point. Concrete should remain in the mixer for at least a minute, and most State Highway Commissions require at least 1½ minutes for mixing. The speed of mixing is not so important as the time, for materials must be thoroughly blended to form good concrete. Dusty or dirty sand, gravel, or crushed stone aggregates will not make strong concrete. Frequently sand and pebbles must be washed as well as screened to remove clay and organic material. Although

concrete should be mixed and placed in the forms as dry as possible, it requires frequent moistening to "cure" it properly. For instance, in highway building, a new concrete road is flooded with water for from ten to fourteen days or is kept moist by a covering of damp earth or straw.

Concrete Mixing Water: The Bureau of Standards recommends the use of a small quantity of calcium chloride in the mixing water of concrete in order to hasten the hardening of the concrete. Tests showed that the addition of calcium chloride to the mixing water up to 10 per cent by weight increases the strength from 30 to 100 per cent over that of concrete in which plain water is used, and that the best results are obtained when from 4 to 6 per cent of calcium chloride is used. While calcium chloride has no harmful effect upon the concrete, it does affect iron and steel, and therefore should not be used for reinforced concrete.

Concrete Mixtures. For water tanks and similar structures subjected to considerable pressure and required to be water-tight, mixtures rich in cement and composed of either 1 : 1 : 2 or 1 : 1½ : 3 concrete are used.

For reinforced floors, beams, columns, and arches, as well as for machine foundations which are subjected to vibration, a 1 : 2 : 4 concrete is generally used. This composition is also employed when concrete is used under water.

For ordinary machine foundations, retaining walls, bridge abutments, and piers in the air, a 1 : 2½ : 5 concrete is satisfactory, and for ordinary foundations, heavy walls, etc., a lean mixture of 1 : 3 : 6 concrete may be used.

Concrete Poles. Concrete poles for transmission lines are of three general types, known as solid, hollow, and trussed poles. In the United States, the majority of poles now in use are of the solid type, whereas in Europe hollow poles are used principally. Solid and hollow poles may have the same outward appearance, being either round, square, hexagonal, octagonal, or square with beveled corners. Reinforcing rods are placed near the outer surfaces, the number of rods varying with the size of pole and the load it must stand. Many square poles have only four rods, one being in each corner. Solid concrete poles have considerable flexibility and strength. A 35- or 40-foot pole fixed solidly in the ground for 6 feet of its length may be deflected from 6 to 8 inches and come back to its normal position, after removal of the load.

Concrete Strength. The compressive strength of concrete which, after having been mixed and laid, has set twenty-eight days, varies from 1000 to 3300 pounds per square inch, according

to the mixture used. If made in the proportion 1 : 3 : 6 (one part cement, three parts sand, and six parts stone or gravel, by volume), using soft limestone and sandstone, a compressive strength of only 1000 pounds per square inch may be expected, whereas a mixture of 1 : 1 : 2, made with soft limestone and sandstone, will have a strength of 2200 pounds per square inch. A mixture of 1 : 3 : 6, made from granite or trap rock, will have a compressive strength of 1400 pounds per square inch, while a mixture of 1 : 1 : 2, made from granite or trap rock, will have a strength of 3300 pounds per square inch. Other mixtures will have values between those given. Concrete may be mixed with cinders, but, in this case, very inferior strength is obtained; the richest mixtures will give a strength of only about 800 pounds per square inch.

Condenser. The purpose of attaching a condenser to a steam engine or turbine is to obtain a reduction in the back pressure, on the exhaust side, by the formation of a partial vacuum in the chamber into which the engine exhausts. The effect of a condenser is either to increase the power of an engine at a given steam consumption or to reduce the steam consumption for a given power. Condensers may be divided into two general classes: In one class the condensing water is mixed directly with the steam, and in the other class the condensing water and steam are kept separate, condensation being effected by contact of the steam with metallic surfaces which are cooled by the continuous circulation of the water. The first class includes jet condensers, barometric or siphon condensers, and the ejector type, whereas, in the second class are the different designs of surface condensers.

Jet Condensers: In a jet condenser, the steam and condensing water mingle in the condensing cone, and the condensed steam is discharged with the water. As the condensing water acts directly upon the steam by actual contact, it will produce a greater drop in pressure for a given amount of water than when used in a surface condenser.

Surface Condenser: In the operation of a surface condenser, the exhaust steam from the engine enters the shell at the top and fills the condensing chamber, flowing around and among the tubes, while the cooling water is made to pass through them by means of the circulating pump. The steam is condensed by contact with the cold surfaces of the tubes, and drops to the bottom of the shell where it flows to one end and enters the air or vacuum pump and is discharged into the hot-well.

Barometric or Siphon Condensers: The barometric or siphon condenser is particularly adapted to plants in which the condensing water is suitable for boiler feeding, and also to any plant where condensation of steam only is desired, the condensing

water not being used. In operation, the condensing water passing through the annular orifice formed by the nozzle flows downward in a cone-shaped film into the combining tube, where its velocity is sufficiently increased to enable it to carry air along with it, thus producing a vacuum in the steam exhaust pipe. The steam flows downward through the regulating nozzle and into the cone-shaped film of water where it is condensed.

Ejector Condenser: The ejector type of condenser is so constructed that the exhaust steam from the engine passes through a series of inclined nozzles and mixes with a stream of condensing water that flows through the nozzles. Ejector condensers may be utilized to draw up the condensing water. The exhaust steam moves with considerable velocity and, when the steam and water meet, the steam is condensed and flows downward with the moving column of water into the hot-well. The discharge end of the pipe is sealed by the water in the hot-well and the velocity of flow overbalances the pressure on the well.

Condenser, Electrical. An electrical condenser, also called a capacitor, is a device for accumulating a large quantity of electricity in static form. Conductors separated by some non-conducting material, called dielectric, form a condenser. A simple form of condenser consists of a large number of sheets of tin foil separated by alternate insulating sheets, such as wax paper or mica. Every other sheet of tin foil is connected together, forming two sets of condenser "plates" and each set is connected to a terminal. If these two terminals are connected with a battery or other source of direct current, an electrostatic charge will be stored up in the condenser. If the battery is disconnected and the condenser terminals connected, the charge will flow out, resulting in a current of short duration. The condenser seems to acquire a counter-electromotive force which becomes equal and opposite to that of the connected battery.

When connected in an alternating-current circuit, although no actual current can flow between the two sets of sheets or plates because of the insulating material between them (except that due to leakage since no material is a perfect insulator), the alternating rise and fall of potential on one side of the condenser will cause a similar rise and fall of potential on the other side of the condenser. Thus, alternating-current power may be transmitted through it. The effect of a condenser in an alternating current circuit might be compared to a flexible disk or membrane in a pipe line which transmitted any fluctuations in pressure without permitting the actual flow of water.

Condensers may be divided into different classes according to the kind of dielectric used, such as air, glass, mica, paper, and electrolytic condensers.

Air condensers are most familiar in the form of variable condensers with aluminum plates used for tuning in a radio set.

Glass condensers are especially adapted to high voltages. The Leyden jar is a well-known form of glass condenser.

Mica condensers are widely used in high-voltage circuits for both power and communication purposes. They are, however, seriously affected by the presence of moisture or any imperfections of the mica surfaces.

Paper condensers are more widely used than any other type. They are generally constructed with metallized paper, tin foil or aluminum foil as "plates" and are impregnated with paraffin or special wax preparations to keep them moisture-proof.

Electrolytic condensers are constructed of metal plates, usually aluminum or tantalum placed in a suitable electrolyte. When placed in this electrolyte, they become coated with a film which is capable of conducting current more freely in one direction than in the other. Below their breakdown voltage, they can hold a large charge in proportion to their conductor surface and this characteristic makes them useful in filter or radio circuits, where large capacitance is needed in compact form. They are, however, very sensitive to temperature changes and operate with a relatively high power loss.

Condenser, Synchronous. When a synchronous motor is operated idly, that is, without carrying any mechanical load, and simply supplies a wattless current for correcting the power factor of an installation, it is termed a *synchronous condenser*. It is used for power-factor correction and for maintaining constant voltage by power-factor control.

Condensite. Condensite is a hard substance used as an electrical insulating material. The chief constituent of condensite is a resinous gum, made by the reaction between phenol and formaldehyde, condensite being produced by combining this gum with a hardening agent at high heat. The advantages of this insulating material are that it is non-inflammable, infusible at any ordinary temperatures, insoluble in oil and in most acids and other solvents, and that it shrinks only 0.2 per cent in molding. It can be used either for plastic molding, or for impregnating wood, paper, cardboard, rubber, leather, etc., or as a cement for fastening together the parts of porcelain insulators, for sealing terminals in porcelain bases, etc. A thickness of 3/16 inch of this material has a puncturing voltage of about 12,000 volts. At a temperature of 170 degrees F., this is reduced to about 5000 volts.

Conduction. See Heat and Heat Transfer.

Conductivity. Conductivity may be defined as the capacity of any substance to conduct an electric current. The conductivity depends largely upon the physical state of the substance. For instance, the conductivity of air decreases very rapidly as its pressure increases, while rarefied air makes a good conductor of electricity. The conductivity of all substances materially alters with a change of temperature, usually decreasing as the temperature increases. The substances which are used for conductors of electricity in commercial work are limited to copper, aluminum, iron and some of their alloys. Of these, the first is pre-eminently the best, while next in order comes aluminum. See Copper Conductivity; also Conductor Materials.

Conductor. A conductor, in the sense in which this word is used in electrical engineering, is a wire or combination of wires not insulated from one another and used for carrying an electric current. Where one or more conductors are insulated from one another but held in the same covering or casing they are usually termed a cord or cable.

The maximum current which a conductor can safely transmit is known as its *carrying capacity.* Heat is developed whenever an electric current flows through a conductor, the amount being directly proportional to the resistance of the conductor and the square of the flowing current. The allowable safe temperature rise is one of the limiting features of the current-carrying capacity of any conductor, and, if the heat develops faster than it can be dissipated from the surface, the temperature will rise. See also Kelvin's Law.

Conductor Materials. The materials most commonly used for electrical transmission are copper and aluminum. Of the two, copper is the better material and is used most extensively. It has a higher conductivity, greater mechanical strength, greater durability, is more ductile, and is not so easily damaged in handling. For sizes of the same conductivity, aluminum wire has about one-half the weight of copper but the diameter is 1.37 times that of copper; consequently aluminum wire exposes a greater surface to wind pressure, and for sleet to form upon, and thereby imposes greater strains on the supporting poles or towers, and limits it use to shorter spans than can be used with copper. Because of the larger diameter and lightness, aluminum conductors are useful for transmitting power at high voltages which would produce a large corona loss with copper conductors having the same conductivity as aluminum. One of the greatest disadvantages of aluminum for conductors is that it has less mechanical strength than copper. This necessitates either using greater sags and higher poles or towers, or spacing the towers closer together.

In either case, the cost of the supporting structures is greater than with copper conductors, and this greater cost will usually more than offset the saving gained by the lower cost of the aluminum conductors. In order to take advantage of the larger bulk and lightness of aluminum, and yet have mechanical strength equal to, or greater than, copper, a composite cable has been put into commercial use. This cable consists of a center core of high strength steel wire wrapped with a number of strands of aluminum wire. The steel is depended upon for the greater part of the supporting strength, although the aluminum wires aid somewhat. In addition to copper and aluminum, bi-metallic copper-steel and steel wires are used. They have lower conductivity than the copper or aluminum, but have greater mechanical strength, and are used for long spans across rivers, etc., for overhead ground wires, and for short lines in which the power to be carried is so small that, if copper wires were used, they would have to be unnecessarily large for mechanical reasons. Bi-metallic wire is a composite wire having a steel center and a copper coating.

Conductor Sizes, Stranded. See Stranded Conductor Sizes.

Cone Clutch. A friction clutch in which one friction surface is in the form of a frustum of a cone and which, for engagement, is forced into the other member which is made to fit it on the inside. One friction surface may be covered with leather. If the angle of the conical surface of the cone type of clutch is too small, it may be difficult to release the clutch on account of the wedging effect, whereas, if the angle is too large, excessive pressure will be required to prevent slipping. The minimum angle for a leather-faced cone is about 8 or 9 degrees and the maximum angle about 13 degrees. An angle of 12½ degrees appears to be the most common and is generally considered good practice. These angles are given with relation to the clutch axis and are one-half the included angle.

Cone Muff Coupling. A coupling consisting of a split sleeve each end of which is cone-shaped on the outside and which surrounds the two ends of the shafts to be coupled together. The sleeve is surrounded by two rings, one on each end, having tapered bores fitting the conical ends of the sleeve. These two rings are clamped together by means of bolts and nuts and in clamping the rings together the split sleeve is forced to bind firmly over the two shafts. See also Compression Coupling.

Cone-Pulley. A cone-pulley is, in reality, a stepped-pulley having, usually, from three to five different diameters for securing a like number of speed variations by shifting a belt from one "step" to another, cone-pulleys being used in pairs with the

largest step of one cone-pulley opposite the smallest step on the other cone-pulley. Usually cone-pulleys are made with uniform steps; that is, the difference in diameter between the various steps is the same. When the centers of the shafts on which the cone-pulleys run are a fair distance apart, so that the belt passes very nearly halfway around each of the cones on which it is running, this method of making the cone-pulleys will prove satisfactory. The length of the belt will then be approximately equal to twice the distance between the shafts added to half the circumference of the step on one of the cones on which the belt is running, plus half the circumference of the step on the other cone engaging with the belt. When the shafts are nearer together, however, so that the belt makes a large angle with the line passing through the centers of the cones, or when there is a large difference between the largest and the smallest steps of the cone, it is not possible to obtain satisfactory results by merely designing the two pulleys with equal differences between the steps, because the length of belt required on the largest and smallest steps will be different from the length required on the two middle steps.

Connecticut River Rule. A rule employed for finding the board measure of logs. It is as follows: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply the result by the length of the log in feet; usually the diameter inside of the bark at the small end is measured.

Connection Bars. The name "connection bars" is usually applied to all connections on switchboards, between apparatus and bus-bars, and between different devices comprising the switchboard equipment. Wire is generally used up to 260 amperes, above which size bars are almost invariably used. Connections are usually bare up to 650 volts; above this voltage and up to 13,200 volts, they are usually insulated; above 13,200 volts, they are, as a rule, bare, and it is considered safer to warn the attendant to keep away from such conductors rather than to depend upon insulation which may deteriorate.

Conservation of Energy. Energy exists in various forms, such as mechanical, molecular, and chemical energy. It is stored in all kinds of fuel, and is made apparent by chemical reactions, by muscular effort, and by other means. Heat is a form of energy and the potential heat energy in coal originally was received from the sun. According to the important law of the conservation of energy, the latter may be transformed directly or indirectly from any one form into any other form, but the total amount of energy must forever remain the same. Energy can

neither be created nor destroyed which accounts for the fact that "perpetual motion" is impossible. The various processes by which energy is utilized are simply means for transforming it from one form into another. The steam engine changes heat energy into mechanical energy, and the percussion of a bullet against a rock converts mechanical into heat energy. A body just at the point of falling from an elevation has a store of potential energy. As it falls its velocity increases, and its potential energy is gradually changed into kinetic energy.

Conservation of Mass. A chemical law applying to all chemical reactions, which states that whenever a change in the composition of substances takes place, the amount of matter after the change is the same as before the change.

Constantan. The alloy known as *constantan* is used for resistance wire in electrical instruments, and also to form one element in base-metal thermocouples. It contains about 60 per cent of copper and 40 per cent of nickel. Its electrical conductivity is only about one-thirtieth of copper; hence, its value as a resistance wire. Its resistance is quite stable over a wide range of temperatures as indicated by its low temperature coefficient of resistance which is about $\pm$ 0.00001 per degree C.

Constants in Mathematics. A constant is a value that does not change or is not variable. However, constants at one stage of a mathematical investigation may be variables at another stage, but an *absolute constant* has the same value under all circumstances. The ratio of the circumference to the diameter of a circle, or 3.1416, is a simple example of an absolute constant. In the common formula used for determining the indicated horsepower of a reciprocating steam engine, the product of the mean effective pressure, the length of the stroke in feet, the area of the piston in square inches, and the number of piston strokes per minute is divided by the constant 33,000, which represents the number of foot pounds of work per minute equivalent to one horsepower. Constants occur in many mathematical formulas and frequently a single value or constant represents one or more other values which have been eliminated to simplify the formula. For example, when there is a constant in both numerator and denominator, the formula may be simplified by dividing the numerator constant into the denominator constant, thus eliminating the former.

Contactors. The magnetically-operated switches of which magnetic control equipments principally consist are known as "contactors." This term is very generally understood as applying to a switch which closes by the application of current to a

magnetic coil and is held closed by the continued application of current to the same coil. Complete lines of contactors have been developed, both for direct and alternating current, which are applicable, by the use of suitable auxiliaries, to any required arrangement of motor circuits. Contactors are designed to operate many thousand times without replacement of electrical parts, and several million times before wearing out mechanically.

Continental Dies. These short-run dies have punches and dies made from steel sheet or plate ranging from 1/8 to 1/4 inch thickness. The punch is usually affixed to a guide plate which lines it up with the opening in the die. See also Dinking Die, and Steel Rule Dies.

Continuous Milling. In any scheme of so-called "continuous milling" the object is to keep the cutters at work the maximum time possible. Continuous milling machines are of the rotary work-table and planer-table types. The rotary table machine is set with its table axis either vertical or horizontal, the work being spaced compactly around the table, and the successive parts milled as they are fed past the revolving cutters. The vertical-axis type has the advantage of easy loading and inspection of the cutter at work, while the horizontal-axis table can be made to work between opposed cutters, which mill the pieces on both ends simultaneously and to length.

The planer-table type of machine may be used for continuous milling in several ways. The work pieces may be strung on the table and milled with the table feeding "against the cutter" until the limit of traverse is reached, the feed then being reversed to travel "with the cutter," after which the work is removed. The objection to this method is the difference in cutter action on the forward and return feed. Another method is to remove parts as soon as they are milled and then return the table by a quick traversing motion. Still another method of continuous milling on planer-type machines is known as the removable platen method. The work is loaded onto a short platen held on a bench alongside of the machine; the platen is then hoisted and lowered onto the ways. A rack on the under side engages the longitudinal feed-screw and feeding toward the cutter begins. Meanwhile, a platen ahead carrying similar parts has passed beyond the cutters and is ready to be unloaded. This is hoisted and trolleyed to the head end of the machine and lowered onto the bench, where the work is removed and more pieces put on. The operation is thus kept up continuously. The minimum number of platens required is two, but three, four or five are often used.

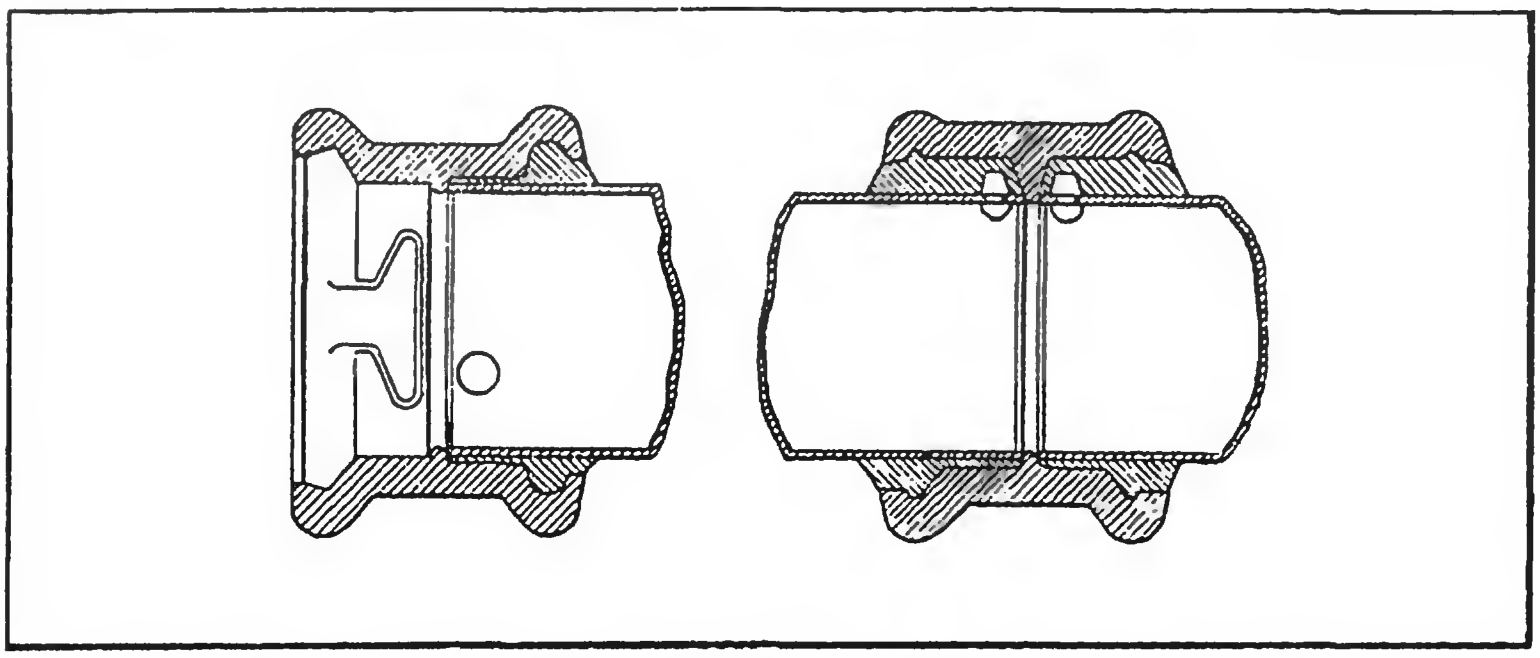
Contracts, Royalty. See under Royalties on Patents.

Controller, Electric. An electric controller is a device or group of devices, which serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected. Included within this definition are the various types of devices used to start, stop, reverse, and control the speed of electric motors. Controllers may be classified as manual, semi-magnetic, and fully magnetic. See also Motors, Control Equipment.

Control Switches. A control switch is used to control the operation of a remote control device, such as a motor or solenoid-operated oil switch, a circuit-breaker, or a rheostat, or a governor motor of a steam engine, water turbine, or other prime mover. It may also be used to close or open circuits, to trip circuit-breakers, oil switches, etc., from some distant point. Control switches are made up in several different forms, such as the plain lever switch type, the drum controller type, and the pull-and-push-button type. They may be single-throw or double-throw, and either single, double, or triple pole, depending upon the service for which they are intended. These switches are usually of small current capacity (under 50 amperes) and are not, in general, called upon to break much current.

Convection. See Heat and Heat Transfer.

Converse Lock-Joint. The Converse lock-joint is a leaded joint used for water piping which does not have to stand very



Converse Lock-Joint

high pressure. The joint consists of a special cast-iron coupling or hub (see illustration) into which the ends of the pipes to be joined are fitted. This hub has an annular groove at each end and, in addition, two T-shaped grooves, one of which is shown in the illustration to the left. The pipe has two holes punched a short distance from the end on opposite sides into which rivets are

driven. One of the holes for the rivets is shown in the illustration to the left, while the rivets themselves are indicated in the section to the right. In making this joint, the heads of the rivets slip into the T-shaped slots of the hub, after which the pipe is turned slightly, locking the pipe into the hub, and preventing it from being pulled out endwise. The joints are then made tight by pouring lead into the annular groove and calking.

Converter. A large pear-shaped vessel holding from ten to fifteen tons of molten iron, employed in the *Bessemer process* for converting pig iron into steel; or the barrel- or trough-shaped vessel used in the refining of copper by a method known as the *Manhes* or *converter process.*

Converters, Synchronous. See Synchronous Converters.

Conveyor. A device for handling and conveying heavy and bulky materials, such as coal and ore, as well as small machine parts of various description, from one part of a plant to another. Conveyors are constructed either to move the material horizontally or to raise it to a higher level. There are different classes of conveyors. See Belt Conveyors; Bucket Conveyors; Screw Conveyors.

Coolant. The term "lubricant" is commonly applied to a fluid used on metal-cutting tools, but as the cooling action of this fluid is by far its most important function, the term "coolant" is more strictly accurate and is now used quite generally. See Cutting Oils and Compounds.

Coordinates. In analytical geometry, coordinates are the distances, measured parallel to the coordinate axes, which locate a point. In plane analytical geometry, there are two coordinates, the *abscissa* and the *ordinate.* In analytical geometry in three dimensions, there are three coordinates.

Copal. Copal is a resinous product used as an electrical insulating material in the form of a colorless varnish obtained by dissolving in alcohol, turpentine, or linseed oil. As an insulating material, it has several disadvantages, however, because it melts at a low temperature, it is very inflammable, and it is brittle, when cold. The puncturing voltage is about 10,000 volts for a thickness of about 1/8 inch, and 20,000 volts for a thickness of about 1/4 inch.

Cope. In foundry practice, the cope is the upper part of a flask used for molding.

Copper. Copper is a very malleable ductile metal that is widely used. The specific gravity of pure copper is 8.94, but varies between 8.91 and 8.95, according to the treatment to which

it may have been subjected. Ordinary commercial copper is somewhat porous and the specific gravity ranges all the way from 8.2 to 8.8. The melting point of pure copper is 1083 degrees C. (1980 degrees F.), but ordinary commercial copper will melt at a somewhat lower temperature, usually about 1940 degrees F. The linear expansion per unit length per degree F. is 0.00000887. The specific heat at 32 degrees F. is 0.0899, and at 212 degrees F., 0.0942. In heat conductivity, copper ranks next to silver, and is superior, in this respect, to all other metals. The heat conductivity is 73.6 per cent of that of silver. In electrical conductivity copper also ranks next to silver, and if the conductivity of silver is assumed as equal to 100, that of copper varies from 96.4 to 97.7, according to its condition.

There are several hundred copper minerals, but the more important ores are not more than about a dozen in number. The most important are the sulphide ores. There are three methods by means of which copper may be obtained from its ores: The first of these methods, the dry method, cannot be profitably employed for ores containing less than 4 per cent of copper. This method is frequently referred to as copper "smelting." The second method, the wet method, is preferred for ores that are very poor in copper, that is, those that contain less than 4 per cent of metal. The third or electro-metallurgical method is very largely used for all classes of ores, but especially for ores containing a comparatively small amount of precious metals, as in this case the ore may be profitably subjected to an electrolytic treatment, the copper being recovered together with the silver and gold present in the ores.

The tensile strength of cast copper varies from 20,000 to 30,000 pounds per square inch; the compressive strength is about 40,000 pounds per square inch; and the modulus of elasticity, 10,000,000. Annealed copper wire has a tensile strength of 35,000 pounds per square inch, and a modulus of elasticity of 15,000,000; unannealed wire has a tensile strength up to 60,000 pounds per square inch, and a modulus of elasticity of 18,000,000.

Copper Alloys. There are many different non-ferrous alloys which contain copper as the chief alloying element. These include many brass and bronze compositions for various purposes. See Brass Alloys for Castings; Brass Sheets; Brass Wire; Brass Rod; Bronze; Admiralty Metal; Aich Metal; Ajax Metal; Baily's Metal; Bell Metal; Benedict Metal; Bismuth Bronze; Chinese Alloys; Constantan; Delta Metal; Dutch Metal; Electrolytic Copper; English Gear Bronze; Gurley's Bronze; Japanese Alloys; Muntz Metal; Ounce Metal; Plastic Bronze; Red Brass.

Copper Alloy Steel. A steel containing a small percentage of copper and nickel, and sometimes chromium, which has been found suitable as a substitute for more expensive alloy steels. A steel containing from 1.5 to 1.8 per cent of nickel and from 0.5 to 0.8 per cent of copper is equal in its properties to a 3 per cent nickel steel. If 0.5 per cent of chromium is added to this alloy steel, the physical properties will equal those of nickel-chromium steel containing 3 per cent of nickel and 1 per cent of chromium.

Copper-Aluminum Alloy. An alloy containing about 90 per cent of copper and 10 per cent of aluminum is remarkable for its high tensile strength, its resistance to corrosion, and its wearing qualities. It is used for worms, accurately fitted bearings, and in places where ability to resist the corrosive action of salt water, and tanning and sulphite liquids is required. The physical properties resemble those of 0.35 per cent carbon Bessemer steel, and are about as follows: Ultimate tensile strength, 70,000 pounds per square inch; elongation in two inches, 20 per cent; reduction in area, 21 per cent; specific gravity, 7.5; Brinell hardness number, 500-kilogram load for 30 seconds, from 90 to 100; shrinkage allowance, 0.22 inch per foot; elastic limit, in compression, 19,500 pounds per square inch. This bronze is about 10 per cent lighter than either yellow brass or manganese-bronze; 17 per cent lighter than phosphor-bronze; and 15 per cent lighter than red brass.

Copper Blast Furnace. A blast furnace used for smelting copper ore. It is much smaller in size than the blast furnace used for iron ores. The furnace is made either round or rectangular in section, the round furnace being used for outputs from 50 to 70 tons a day, and the rectanglar furnace for larger amounts. The round furnace may be up to 4 feet in diameter and is made 14 feet high. Rectangular furnaces are made not more than 4 feet wide and are also made 14 feet high, but are made as long as required.

Copper Castings. So-called "pure copper" castings ordinarily contain from one to three per cent of zinc. These are used in electrical installations and for die-blocks on electric welding machines. The conductivity, as compared with silver = 100, is not more than 60 per cent. Pure commercial copper containing from 99.6 to 99.9 per cent of metallic copper has a conductivity from 70 to 85 per cent of that of pure silver. Hence, the impurities in ordinary copper castings impair, to a great extent, its value as an electrical conductor.

Copper-Clad Steel. A material generally used in the form of wire, in which a steel wire is covered with a coating of copper. It is produced either by alloying the copper with the surface of the metal or by welding it onto the surface. When the copper is alloyed with the surface, it is brought to a molten state before being applied, while, when welded to the surface, it is merely in a plastic state.

Copper Coloring. To color copper articles, such as ash trays, pin dishes, receivers, etc., a solution of ammonium sulphide will give good results for the beginner. The greatest variety of colors, from light brown to black, can be obtained by this simple method. Use a dilute solution, cold. A good working solution is produced by diluting a saturated solution of ammonium sulphide with from 10 to 40 parts of water. A light brown color is produced by dipping the work for a very short time in the solution, withdrawing it, and allowing it to dry in the air. A darker shade of brown is obtained by a longer immersion, according to the color desired, after which the work is allowed to dry in sawdust. To obtain a black coloring, allow the article to remain for some time in the bath, and, after removing, dip it in alcohol, after which the alcohol is burnt off, leaving a black coating. These colors can be permanently fixed by a transparent lacquer. The objection to ammonium sulphide is the great care necesary in handling, as it leaves an indelible stain upon the fingers, and also has a very obnoxious odor. The ammonium sulphide also decomposes in time, depositing sulphur. It should be kept in a dark-colored bottle provided with a glass stopper. It is not good for brass, being adapted only for copper.

Another solution for coloring copper which yields very good results is composed of copper nitrate, 1 part; water, 3 parts. This solution forms a deposit of copper salt, and, if heated, the salt is decomposed into a black copper oxide. The greenish tints are obtained by the following solution: Ammonium carbonate, 2 ounces; ammonium chloride, 2/3 ounce; water, 16 ounces. This solution gives good results on both copper and brass, different colorings being obtained by repeated dippings in the solution, allowing ample time between each for the articles to properly dry.

Copper Conductivity. The following are the normal values for standard annealed copper according to the Standardization Rules of the American Institute of Electrical Engineers.

1. At a temperature of 20 degrees C., the resistance of a wire of standard annealed copper one meter in length and of a uniform section of 1 square millimeter is 1/58 ohm = 0.017241 ohm.

2. At a temperature of 20 degrees C., the density of standard annealed copper is 8.89 grams per cubic centimeter.

3. At a temperature of 20 degrees C., the "constant mass" temperature coefficient of resistance of standard annealed copper, measured between two potential points rigidly fixed to the wire, is 0.00393 = 1/254.45 per degree centigrade.

4. As a consequence, it follows from (1) and (2) that, at a temperature of 20 degrees C., the resistance of a wire of standard annealed copper of uniform section, one meter in length and weighing one gram, is $1/58 \times 8.89 = 0.15328$ ohm.

Copper Hardening. It is quite commonly believed that the hardening of copper as practiced by the ancients is a "lost art," but present-day metallurgists not only understand how the ancients hardened their copper and bronze, but also know how to produce copper and bronze products that are even harder than specimens which have been discovered. Cutting edges on swords, daggers, knives and other implements developed by the ancients were obtained by hammering the metal, or, in other words, cold-working. These old metal-workers not only hand-hammered their copper implements but also used the same means to harden bronze articles.

There are two methods of hardening copper. One consists of alloying the copper with some other metal or several other metals, such as zinc, tin, nickel, cadmium, chromium, cobalt, silicon, aluminum, iron, beryllium and arsenic; the second consists of cold-working the metal or copper alloy. In fact, it is possible to work the metal to such a state of hardness that a slight amount of additional work will cause it to break. The explanation of all copper hardening may be attributed to one of these methods or a combination of both. Photomicrographs of an ancient copper spear-head indicate that apparently this hardness had been obtained by cold-working. It is possible to produce copper scissors, knives, and other cutting tools, but unless a special reason exists for their use, they offer no advantages over tools made from steel. The actual hardness of annealed commercial copper as determined by the Brinell machine is from 40 to 50. The hardness of cold-worked pure copper probably does not ever exceed 120 Brinell. The hardness of copper that has been alloyed with some other metal or a number of metals rarely exceeds 250 Brinell, although a hardness just over 300 has been attained as an upper limit. As a basis of comparison, the Brinell hardness of very "soft" iron is around 80, and of steel used in common cutlery, such as in a pocket-knife, about 420 Brinell.

Coppering Solution. A coppering solution for coating finished surfaces, in order that lay-out lines may be seen more easily, is composed of the following ingredients: To 4 ounces of

distilled water (or rain water) add all the copper sulphate (blue vitriol) it will dissolve; then add 10 drops of sulphuric acid. Test by applying to a piece of steel, and, if necessary, add four or five drops of acid. The surface to be coppered should be polished and free from grease. Apply the solution with clean waste, and, if a bright copper coating is not obtained, add a few more drops of the solution; then scour the surface with fine emery cloth, and apply rapidly a small quantity of fresh solution.

Copper Loss. The loss of energy which takes place when a current passes through a conductor, whether an armature winding or a transmission wire, is called *copper loss.* It is due to the resistance of the wire which causes a partial transformation of electrical energy into heat energy. The loss may be computed by multiplying the square of the current in amperes by the resistance of the conductor in ohms. The loss is then obtained in watts.

Copper Wire Strength. The strength of copper wire can be greatly increased by proper methods in the drawing operation. It has been found that the strength can be increased nearly 100 per cent by omitting the annealing process during the latter part of the drawing, at the same time making the steps of gradations between the successive dies smaller. In this manner, copper wire will obtain a very hard surface, and is known as "hard drawn." The increase in strength is greater for smaller diameters, as the treatment will affect a proportionately larger part of the cross-section. A No. 8 copper wire (0.165 inch in diameter) can be given a strength of 62,000 pounds per square inch of cross-section, while a No. 12 wire (0.104 inch in diameter) may obtain a strength of 64,500 pounds per square inch. As ordinary commercial copper wire has a tensile strength of only 32,000 pounds per square inch, the effect of correct methods in drawing is very marked. The modulus of elasticity is increased by these methods from 12,000,000 to 19,000,000 pounds, but the elongation is reduced from 35 to 1.25 per cent. It should be noted that this change is effected entirely by manipulation in the drawing, and not by the addition of any alloying metal.

Coprtex. Heat-insulating cement made from a base material of resilient long-fiber copper slag wool. The cement will bond and stick to clean surfaces of any type of material. Average adhesive strength, 30 pounds per square inch. It will withstand a temperature of 2000 degrees F. The high-temperature Coprtex blocks weigh 22 pounds per cubic foot; their maximum temperature limit is 1800 degrees F. The cement is suitable for making repairs or changes in steam lines, headers, boilers, or similar

equipment. High-temperature blocks may be used where superior insulating efficiency is required.

Cord. In the measure of wood, a cord, equals a pile 4 by 4 by 8 feet, or a cubical content of 128 cubic feet.

Cordeaux Thread. The Cordeaux screw thread derives its name from John Henry Cordeaux, an English telegraph inspector who obtained a patent for this thread in 1877. This thread is used for connecting porcelain insulators with their stalks by means of a screw thread on the stalk and a corresponding thread in the insulator. The thread is approximately a Whitworth thread, 6 threads per inch, the diameters most commonly used being $\frac{5}{8}$ or $\frac{3}{4}$ inch outside diameter of thread; $\frac{5}{8}$ inch is almost universally used for telegraph purposes, while a limited number of $\frac{3}{4}$-inch sizes are used for large insulators.

Core Boards. See Cores for Molds.

Core-Boxes. See Cores for Molds.

Core Loss. The power lost in an iron core of an electrical machine on account of hysteresis and eddy-currents, taken together, is called *iron loss* or *core loss*. These losses bring about a lowering of the efficiency of the machines, and also cause a heating up of the iron, and thus limit the permissible flux density, or make extra provisions for ventilation and cooling necessary.

Core Print. Many patterns for use in making castings, have projections which form pockets in the mold which can be used in supporting cores to form interior openings in the castings. These projections are called *core prints* as they leave a print or impression in the mold. The core, which has extensions for entering these prints, is made in a separate wooden mold or core-box and it is reinforced with iron rods or wire and baked in an oven to give it greater strength. There are three types of core prints in general use on patterns. Those that are placed on the cope and drag side of a pattern are called *cope* and *drag prints;* those located on the sides or ends, or in any position where there is a joint or parting, are known as *joint* or *parting prints;* and those which are so placed that no parting can be made are called *tail, heel,* or *drop prints.*

Cores for Molds. Cores for forming passages or openings in castings are of three kinds: 1. Metal cores. 2. Dry sand cores. 3. Green sand cores. A *metal core* is used in brass or non-ferrous metal work when considerable accuracy in the core is required. Cores of this kind are not used in cast-iron molding. A *dry sand core* is one that is made from a fairly coarse sand

free from clay, the sand being mixed with a bond or binder until it is of about the consistency of heavy flour dough. It is then baked until perfectly dry and hard. A *green sand core* is one which is made from ordinary molding sand—green sand—and which is not baked. This is, by far, the cheapest form of core which can be used; but it is restricted to comparatively simple shapes—usually plain cylindrical shapes—or to pattern forms in which there is a recess, so that the core can be shaped by molding the sand in connection with the regular molding work.

Oil-sand Cores: For certain classes of core work, excellent results are obtained by the use of sea sand and oil, such as, for instance, the core required for the combustion chamber of a gas or oil engine, or the steam ports of cylinders, when the core is entirely surrounded, and good venting is necessary. Oil-sand cores are very hard and strong, when dry. The principal objection to this kind of core is the disagreeable odor emanating from the oil. The fact that the oils generally used are fish oils is responsible for this odor, but a mixture of 2 parts of whale oil with 1 part of boiled linseed oil gives good results, and has not such an offensive odor. There are also several good core oils on the market which have practically no odor.

Core-boxes: After the shape or design of a dry sand core has been determined by the patternmaker, a mold must be constructed in which the core may be formed. This mold is called a *core-box*, and should always be marked in such a way that it will be kept with the pattern to which it belongs. The making of core-boxes for dry sand cores is an important part of the patternmaker's work. There are two general classes of core-boxes, *viz.*, those that form complete cores and those that form cores partly by means of the core-box and partly by strickling; the latter are called *skeleton* or *frame* core-boxes.

Core Boards: Core boards are used when sweeping up cores with strickles. The outline of the board governs the lengthwise form of the core, while the strickles give it sectional shape. Core boards are used largely for pipe work and where but one or two castings are to be made. A core made on a board cannot be removed until it is dried, so that the board must be put in the oven along with the core. These boards do not last very long when made of wood, and if they are to be used a number of times, it is preferable to make them of cast iron.

Core Machines: When many cores are to be made of small size and cylindrical in shape, core machines are sometimes used to good advantage. The advantages of core-making machines are that the work is produced more rapidly and uniformly than by hand and no core-boxes are required.

Core-barrel: A core-barrel, generally made from cast iron, is

employed in the making of large cores in the foundry. Instead of making the cores solid, loam is applied to the outside of the core-barrel, the barrel being first wound with rope and the loam mixture applied in a comparatively soft state. The barrel is turned during this process so that the core is formed to a circular section at all points by means of a strickle, which may be shaped to form any contour on the surface of round cores.

Core Oven: Ovens used for drying cores in the foundry generally are made large enough so that a truck with a table and shelves for supporting the cores may be wheeled right into the oven. Shelves are sometimes provided on the sides of the oven on which to place the cores.

Corex. An abrasive which is used in the manufacture of wheels for grinding cast iron, unannealed malleable iron, brass, bronze, etc., is known as *corex.* It is produced from coke and sand in the electric furnace.

Cork. Cork is obtained from the outer layer of the bark of an evergreen species of oak, growing in the south of Europe and on the north coast of Africa. Water and many liquids have no deteriorating effect upon cork, and it may be compressed many thousand times without changing its molecular structure. An important application of cork is for cork inserts in friction clutches, owing to the fact that cork has a high coefficient of friction, probably double that of wood or leather on iron. As a rule, the cork, which has previously been boiled and softened, is forced into holes formed in one of the metallic friction surfaces so that it slightly protrudes above the surface. When the clutch is engaged, the cork will engage the opposing friction surface first, but if sufficient pressure is applied to the clutch, the cork is pressed down flush with the metal surface and acts with it in carrying the load. The coefficient of friction with cork-insert surfaces has been found to average about 0.34, while the average coefficient of friction of cast iron on cast iron is about 0.16, and of bronze on cast iron, about 0.14.

Corona Loss. When the voltage of an overhead transmission system or of conductors in general exceeds a certain critical value, depending upon the spacing and diameter of the wires, there will appear on the surface of the conductors a halo-like glow to which the name "corona" has been given. This is due to the ionization of the air or other gas surrounding the conductors by the electric field and causes an increase in conductivity of the air or gas. Apart from this luminous effect, the appearance of the corona is accompanied by a certain loss of power, proportional to the frequency and the square of the amount by which the potential difference between the conductors exceeds a certain value known

as the "disruptive critical voltage." The action of corona on insulation manifests itself chemically, mechanically, or by heat. At high altitudes particularly it is not advisable to use the smaller sizes of wire for high voltage transmission of power because of this corona loss.

Corowalt. Corowalt is a special corundum abrasive that is adapted for grinding hardened low- or high-carbon steel. Corowalt is produced in the electric furnace in a manner similar to that of alundum.

Corrosion. The forming of an oxide on the surface of a metal; specifically, the forming of rust (iron oxide) on the surface of iron and steel.

Corrosion Fatigue. The corrosion fatigue of metals from their exposure to corrosion simultaneously with the application of stress. There are two stages in the process. The first stage is accelerated pitting owing to the influence of cyclic stress on corrosion. As pitting increases, the actual stress at the bottom of the pit increases. When this increased stress surpasses the endurance limit of the metal, the second period of corrosion fatigue begins and the metal is subjected to ordinary fatigue as well as to the accelerated corrosion pitting. The principal factors involved are susceptibility of the metal to pitting action, corrosiveness of the solution, time, cycle frequency, stress, and development of protective films. Metals and alloys have no inherent corrosion fatigue limits because damage depends always on the corrosiveness of the solution and the duration of the exposure.

Extremely important practical features in services involving corrosion fatigue are: (1) the advantage of heat-treated and cold-worked materials over annealed materials tends to be reduced; (2) fatigue and endurance values are reduced considerably in corrosive environments under severe cyclic service; (3) severe pitting will result in premature failure due to notch-fatigue; and (4) significant weight loss or decrease in diameter in the case of wire will increase the unit stress correspondingly to cause premature failure.

For these reasons, fatigue and endurance values determined in air at room temperature cannot be used for design of springs for corrosive service. If adequate corrosion-fatigue data, based on long-time tests, are not available, trial runs in prototypes or pilot models are necessary to determine the suitability of springs in a corrosive environment before design dimensions are fixed. Such tests should be run for several months and the surface examined periodically to determine significant tendencies toward weight loss and susceptibility to pitting.

Corrosion-resistant Steels. Corrosion resistant steels or wrought stainless steels are divided into three broad groups or types according to their composition and physical characteristics.

Stainless Chromium-Nickel Austenitic Steels (Not Hardenable)—These steels are austenitic at room temperature and higher and cannot be hardened by thermal treatment.

S.A.E. 30301: This steel is capable of attaining high tensile strength and ductility by moderate or severe cold working. It is used largely in the cold rolled or cold drawn condition in the form of sheet, strip and wire. Its corrosion resistance is good but not equal to S.A.E. 30302. *S.A.E. 30302:* This is the most widely used of the general purpose austenitic chromium nickel stainless steels. It is used for deep drawing largely in the annealed condition. It can be worked to high tensile strengths but with slightly lower ductility than S.A.E. 30301. *S.A.E. 30303F:* This is a free machining type recommended for the manufacture of parts produced on automatic machines. Caution must be used in forging this steel. *S.A.E. 30304:* This is similar to S.A.E. 30302 but somewhat superior in corrosion resistance and having superior welding properties for certain types of equipment. *S.A.E. 30305:* Similar to S.A.E. 30304 but capable of lower hardness. Has greater ductility with slower work hardening tendency. *S.A.E. 30309:* This steel has high heat resisting qualities and is resistant to oxidation at temperatures up to about 1800 deg. F. *S.A.E. 30310:* This steel has the highest heat resisting properties of any of the chromium nickel steels listed herewith and is used to resist oxidation at temperatures up to about 1900 deg. F. *S.A.E. 30316:* This steel is recommended for use in parts where unusual resistance to chemical or salt water corrosion is necessary. It has superior creep strength at elevated temperatures. *S.A.E. 30317:* This steel is similar to S.A.E. 30316 but has the highest corrosion resistance of all these alloys in many environments. *S.A.E. 30321:* This steel is recommended for use in the manufacture of welded structures where heat treatment after welding is not feasible. It is also recommended for use where temperatures up to 1600 deg. F. are encountered in service. *S.A.E. 30325:* Used for such parts as heat control shafts. *S.A.E. 30347:* This steel is similar to S.A.E. 30321 with the following additional statement. This columbium alloy is sometimes preferred to titanium because less columbium is lost in the welding operation.

Stainless Martensitic Chromium Steels (Hardenable)—These steels may contain small amounts (up to 3 per cent) of nickel. They are ferritic at room temperature but become austenitic at elevated temperature and can be rapidly cooled to produce a hard,

martensitic structure in the same manner as other hardenable steels are heat-treated.

S.A.E. 51410: This is a general purpose stainless steel capable of heat treatment to show good physical properties. It is used for general stainless applications, both in the heat treated and annealed condition but it is not as resistant to corrosion as S.A.E. 51430 in either the annealed or heat treated condition. *S.A.E. 51414:* This is a corrosion and heat resisting nickel-bearing chromium steel with somewhat better corrosion resistance than S.A.E. 51410. It will attain slightly higher mechanical properties when heat treated than S.A.E. 51410. It is used in the form of tempered strip or wire, and in bars and forgings for heat treated parts. *S.A.E. 51416F:* This is a free machining grade for the manufacture of parts produced in automatic screw machines. *S.A.E. 51420:* This steel is capable of heat treating to a relatively high hardness. It will harden to a maximum of approximately 500 Brinell. It has its maximum corrosion resisting qualities only in the fully hardened condition. It is used for cutlery, hardened pump shafts, etc. *S.A.E. 51420F:* This is similar to S.A.E. 51420 except for its free machining properties. *S.A.E. 51431:* This is a nickel bearing chromium steel designed for heat treatment to high mechanical properties. Its corrosion resistance is superior to other hardenable steels. *S.A.E. 51440A:* A hardenable chromium steel with greater quenched hardness than S.A.E. 51420 and greater toughness than S.A.E. 51440B and 51440C. Maximum corrosion resistance is obtained in the fully hardened and polished condition. *S.A.E. 51440B:* A hardenable chromium steel with greater quenched hardness than S.A.E. 51440A. Maximum corrosion resistance is obtained in the fully hardened and polished condition. Capable of hardening to 50-60 Rockwell C depending upon carbon content. *S.A.E. 51440C:* This steel has the greatest quenched hardness and wear resistance upon heat treatment of any corrosion or heat resistant steel. *S.A.E. 51440F:* The same as S.A.E. 51440C, except for its free machining characteristics. *S.A.E. 51501:* Used for its heat and corrosion resistance and mechanical properties at temperatures up to about 1000 deg. F.

Stainless Ferritic Chromium Steels (Not Hardenable)—These high-chromium, low-carbon steels are ferritic at room and elevated temperatures. They cannot be hardened by heat-treatment.

S.A.E. 51430: This is a steel of a high chromium type not capable of heat treatment and is recommended for use in parts of moderate draw. Corrosion and heat resistance are superior to S.A.E. 51410. *S.A.E. 51430F:* This is similar to S.A.E. 51430 except for its free machining properties. *S.A.E. 51442:* A corrosion and heat resisting chromium steel with corrosion resisting

properties slightly better than S.A.E. 51430 and with good scale resistance up to 1600 deg. F. *S.A.E. 51446:* A corrosion and heat resisting steel with maximum amount of chromium consistent with commercial malleability. Used principally for parts which must resist high temperatures in service without scaling. Resists oxidation up to 2000 degrees F.

Corrugated Flanges. The plain face corrugated type of joint for pipe flanges is a plain face straight flange upon which concentric curves have been cut with a round-nosed tool. This joint has a tendency to resist blowing out of gaskets especially when thick gaskets are used.

Plain Face Scored Joints: This type of joint employs plain straight flanges with scores upon their faces consisting of concentric rings made with a diamond-pointed tool.

Corubin. Corubin is an artificial corundum obtained from the slag produced by the Goldschmidt thermit welding process. It is much purer than the natural corundum and will resist sudden and great changes of temperature without breaking. Chemical vessels made of fireclay and corubin may be heated red-hot and plunged into cold water without breaking, or even showing any tendency to crack.

Corundum. Corundum is an aluminum oxide which is found in nature as crystals which are usually rough and rounded, or massive, with nearly rectangular partings. There are many varieties of corundum, the finely-colored transparent varieties including such gem-stones as the ruby and sapphire, while the impure granular, and massive forms are known as *emery*. The term "corundum" is often restricted to the remaining kinds; that is, those crystallized and crystalline varieties which are not sufficiently transparent and brilliant for ornamental purposes and which were known to the older mineralogists as "imperfect" corundum. Corundum is superior to emery as an abrasive, because the impurities found in emery are almost entirely absent in corundum; the latter also contains a much larger percentage of crystalline alumina, which is the element in both abrasives that possesses cutting qualities.

The percentage of crystalline alumina found in corundum obtained from the different sections is approximately as follows: Canadian corundum, from 90 to 95 per cent; Georgia corundum, 77 per cent; Brazilian corundum, 76 per cent; India corundum, 73 per cent. In Canadian corundum, iron oxide, which is the most objectionable impurity in emery, is as low as 1¼ per cent, as compared with 25 per cent in Naxos emery. Corundum is

harder than emery, and, therefore, the abrasive grains will remain sharp longer. The Canadian corundum is mined in Eastern Ontario, where there are very large and practically inexhaustible deposits. The corundum occurs in hexagonal crystals imbedded in felspar, syenite, chlorite, and occasionally in some other non-metallic minerals or gangues. Only the crystals are used, all of the felspar and other gangues being removed by crushing the material and passing it over concentrating jigs and tables, and over magnets and blowers.

Cosecant of Angle. See Functions of Angles.

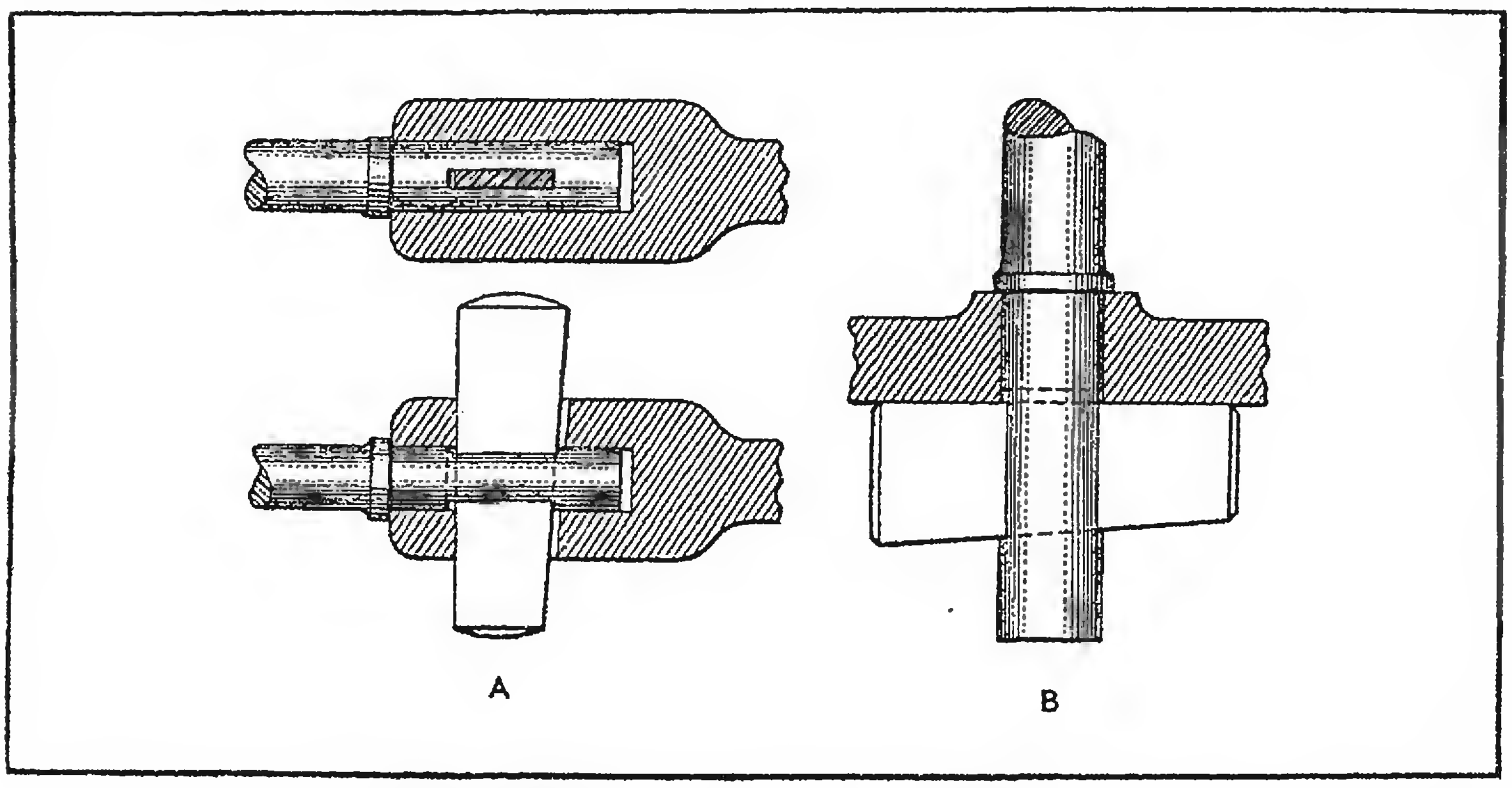
Cosine of Angle. See Functions of Angles; also Law of Sines and Cosines.

Coslettizing. Coslettizing is a process for rust-proofing iron and steel. A solution is made from one quart of concentrated phosphoric acid, one quart of water, and one pound of iron filings. This mixture is allowed to stand until the iron is entirely dissolved, and then it is added to water in the proportions of one part of solution to 50 parts of water. The work to be treated is first cleaned as for plating, either by scratch-brushing or by immersion in a muriatic-acid dip, in order to remove any rust that may be present. The parts are suspended in the solution by means of iron wire or hooks, or, in the case of small articles, by placing in iron or earthenware baskets. The solution must be kept close to the boiling point, and the articles are allowed to remain in it for from ½ to 3 hours, depending upon the nature of the work, a heavy coating being produced in from 2 to 3 hours time. A convenient arrangement for the bath is to make up the solution in an enamel or agateware tank, and heat this tank by placing it in boiling water. After the articles are removed from the solution, they should be allowed to dry in the air, and may then be scratch-brushed on a fine wire wheel, revolving at 600 revolutions per minute, and oiled with linseed or paraffin oil. Another solution is composed of 6 ounces of zinc, 1 pint of phosphoric acid, and 1 pint of water, making a stock solution which is diluted by using 1 ounce of stock solution per gallon of water. The treatment of the work is the same as for the other solution.

Cotangent of Angle. See Functions of Angles.

Cotter. A cotter is a form of key that is used to connect rods, etc., that are subjected either to tension or compression or both. Diagram *A* shows how a cotter is used to hold the valve-stem and valve-rod of an engine together. The cotter is of rectangular section and the edges may be either square or rounded, the latter form being generally used. It is driven transversely through the two members to be held together and the slots are

offset somewhat so that the cotter forces the inner rod (in this particular case) against its shoulder. Frequently, a taper fit is employed instead of a cylindrical fit and shoulder, in which case the rod is drawn tightly into the taper hole. In some cases, a cotter simply passes through the end of a rod as shown at *B*.



Two Methods of Applying Cotters

Cotter Files. These files are made in both taper and blunt forms, and from pillar sections. They are double-cut, mostly bastard, and principally used for filing the grooves for cotters, keys, etc.

Cotter-Pins. The cotter-pin or split pin is used to prevent pins and other parts from working out of their holes, and nuts from unscrewing. After the pin is inserted through a small hole in the part to be kept in place, the ends are spread apart. The nominal "trade diameter" is the diameter of the pin before the sections are divided or expanded. The S.A.E. Standard diameters are 1/16, 3/32, 1/8, 5/32, 3/16, 7/32, 1/4 and 5/16 inch. The lengths under the head vary from 5/16 inch for the 1/16-inch size up to 3 inches for the 7/32 to 5/16-inch sizes.

Cotton Gin. The cotton gin was invented by Eli Whitney in 1792. This is one of the few great inventions which is due entirely to the work of one man. As the great importance of this invention was generally recognized, many came to see the machine even before patent rights had been granted. The privilege of inspection was denied in order to safeguard the invention, but the building was broken into at night and the machine removed; consequently, its construction was no longer a secret and before Whitney could secure a patent, a number of machines were in successful operation which deviated only slightly from the

original design. The result was that Whitney had considerable trouble later in establishing rights to the invention.

Coulomb. A coulomb is the quantity of electricity transmitted by a current of one ampere in one second. It is also equal to the quantity of electricity contained in a condenser with a capacity of one farad, when the same is subject to an electromotive force of one volt. One ampere-hour is equal to 3600 coulombs. The International Electrical Congress, held in Chicago in 1893, recommended the adoption of the coulomb as the unit of quantity of electricity, and, by Act of Congress, July 12, 1894, this has been made the legal unit in the United States.

Counterboring. This operation is for the purpose of enlarging some part of a cylindrical bore or hole. For example, if a machine screw hole is enlarged at one end to receive a fillister-head screw, this is counterboring and the tool used is known as a *counterbore*. Counterboring is also done in connection with lathe and boring-mill work, as, for example, when the bore of a cylinder is enlarged at the ends to form a clearance space or counterbore, as it is called.

Counterboring Tool. The tool known as a counterbore is used for enlarging previously drilled holes in such a manner that the bottom of the enlarged hole has a square shoulder. The tool consists of a body part, the end of which is provided with cutting edges, a guide or "pilot" which accurately fits the hole already drilled, and a straight or taper shank by which the counterbore is held and driven.

Counter Cells. Counter cells are used for reducing the charging voltage when charging storage batteries. These cells have two electrodes of pure lead without any active material, but the electrolyte. They give practically constant potentials for all currents passing through them, but no power. The positive electrode of a counter cell is connected to the positive pole of the main cell, so that the potential of the counter cell opposes that of the main cell.

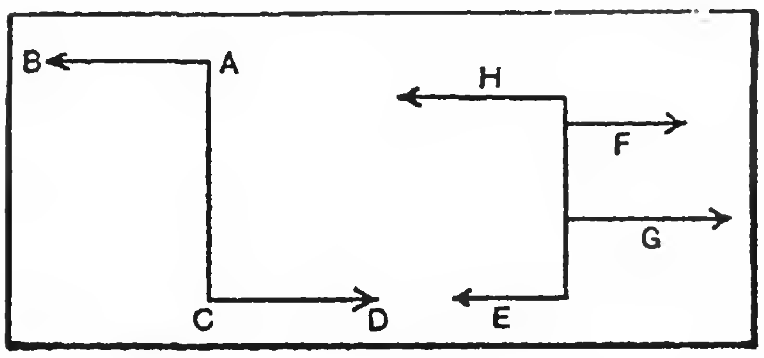
Counter-Electromotive Force. The counter-electromotive force is the voltage which opposes the flow of current through a conductor whenever that conductor is moving through an opposing electromagnetic field. Thus, there are two sources of electromotive force in the windings of a motor that is running: (1) The voltage which is impressed on the armature or rotor from an outside source; (2) the voltage which is set up by the armature or rotor windings in cutting the lines of force or magnetic flux set up by the field. These electromotive forces are opposite in direction, and the latter is called the counter-

electromotive force, because it opposes the electromotive force impressed across the armature to cause it to turn as a motor. The current that flows is proportional to the difference between the two voltages.

Countershafts. A countershaft is a short shaft which is driven from a main shaft and serves either to start or stop a machine independently of other machines which may be driven from the same main shaft. With the usual arrangement, the countershaft is driven by a belt and transmits motion to the driven machine by another belt. There are several types of countershafts, some of which are arranged for reversing the direction of rotation, whereas others provide two or more speed changes.

Countersinking. On some classes of work, screws having heads that are conical on the under side are used. Forming a conical seat for a head of this shape is known as *countersinking*. The operation is similar to counterboring, except that a tool for forming a conical seat has cutting edges which incline to suit the required angle. The pilot form of countersink is used after the hole for the screw-body has been drilled. Countersinks are also used which have a drill of the proper size at the end, instead of a pilot, so that the straight and conical parts of the hole are finished in one operation.

Counting Board. A tray provided with a large number of semi-spherical depressions, usually 1000, which is employed for the counting of steel balls. By filling the tray with balls until one ball rests in every depression, the counting of balls in great quantities is easily done, one operator being able to count as many as a million balls a day.



Couples of Forces

Couples of Forces. If the forces *AB* and *CD* (see illustration) are equal and parallel, but act in opposite directions, then the resultant equals 0, or in other words, the two forces have no resultant and are called a *couple*. A couple tends to produce rotation. The measure of this tendency is called the *moment of the couple*, and is the product of one of the forces multiplied by the distance between the two. As a couple has no resultant, no single force can balance it, or counteract the tendency of the couple to produce rotation. To prevent the rotation of a body acted upon by a couple, two other forces are, therefore, required, forming a second couple. The moment of this couple must be equal to

the moment of the couple which it balances. In the illustration, E and F form one couple and G and H are the balancing couple. The body on which they act is in equilibrium if the moments of the two couples are equal and tend to rotate the body in opposite directions.

Couplings of Electric Type. In couplings of this type, the driving and driven members are not connected mechanically. For example, the Diesel engines of a motorship equipped with this type of coupling have no mechanical connections between them and the gears that turn the propeller. Power is transmitted from the engines to the gears through these couplings which provide an electric cushion, as the power is transmitted electrically across the air gaps of the couplings. They prevent the pulsations of engine torque from reaching the gears, and also enable the engine to be connected to the propeller instantly.

A coupling consists of two rotating members, revolving one inside the other. One is mounted rigidly on the engine shaft, and the other is connected to the gear. The external member has salient field poles, connected to the ship's direct-current auxiliary power supply for excitation. Rotating inside this field is the inner member with a squirrel-cage winding. The mechanical rotation of the field member creates a rotating magnetic field which induces currents in the squirrel cage. The interaction of the resulting magnetic fields creates powerful forces which cause the squirrel cage to follow the field except for a small slip, just as the secondary of a squirrel-cage induction motor follows the rotating magnetic field set up by the stator. The efficiency of these couplings is 97.5 per cent approximately.

Couplings of Fluid Type. Couplings of the fluid or hydraulic type are now being used both in automobile transmissions and for certain industrial applications. With couplings of this general type, the motion of the driving member is transmitted to the driven member through the medium of an oil fluid rather than by direct physical contact. The effectiveness of the fluid coupling depends upon this feature, which, in the case of automobile transmissions, for example, permits a gradual shockless acceleration of the driven part up to the point where its speed is nearly the same as that of the driver. The operation of all couplings of this type is due to the action of centrifugal force upon the fluid, in conjunction with the design of the driving and driven members. Just how it is possible to transmit not only motion but considerable power through an oil fluid, and without direct contact between driving and driven members, will be explained in connection with the particular design of fluid coupling used in the Oldsmobile transmission.

Fluid Coupling in Oldsmobile Transmission: The fluid coupling is an important feature in the Hydra-Matic drive of the Oldsmobile cars. While this coupling operates in conjunction with a fully automatic four-speed transmission, the coupling only will be described. The general arrangement of this coupling is illustrated by the diagram. An impeller *A* and a runner *B* are enclosed in a housing containing an oil fluid selected to function

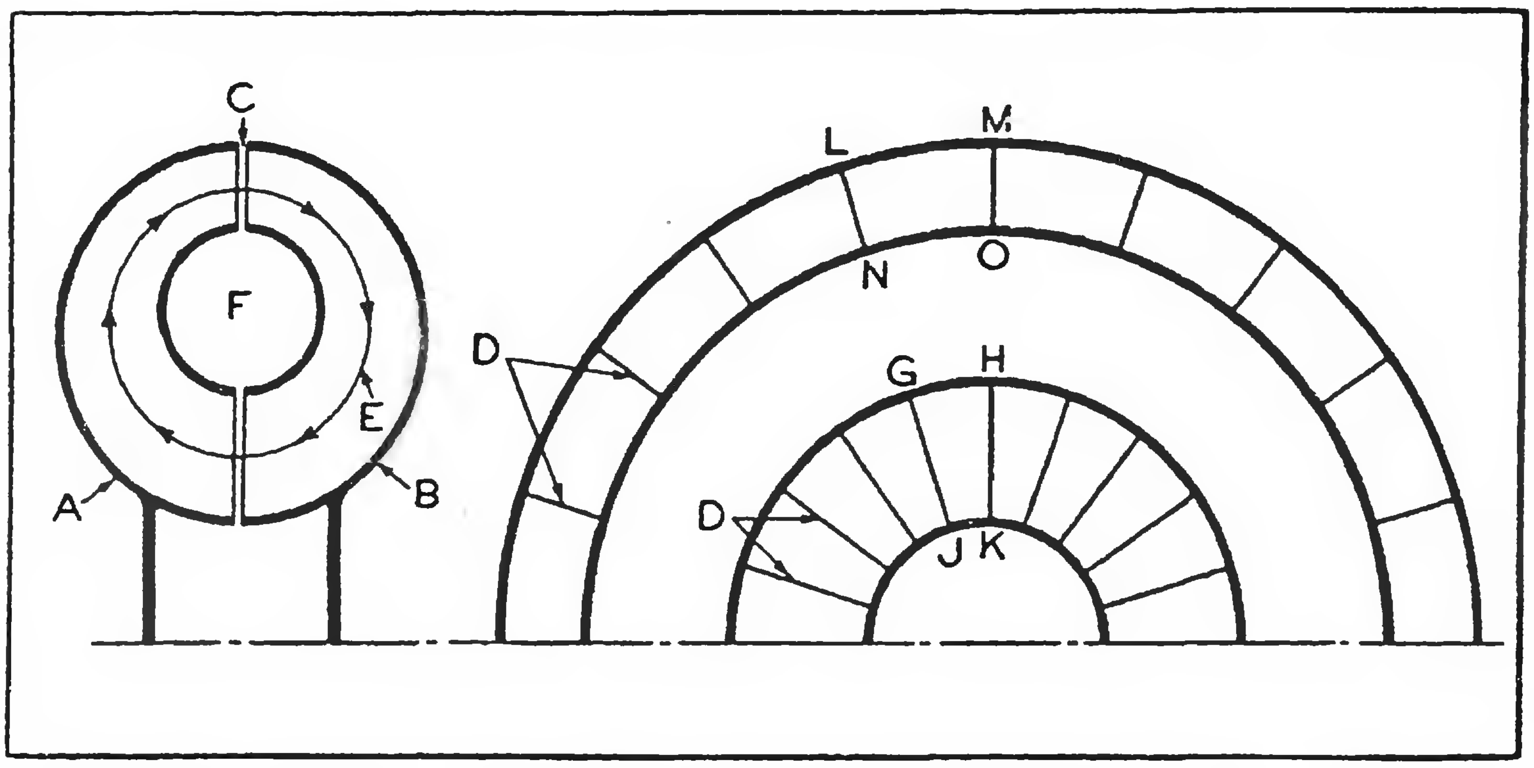


Diagram Illustrating General Arrangement of a Fluid Coupling

under a wider range of temperatures than are likely to be encountered. The impeller is driven by the engine (through a planetary gear set which, when in reduction, brings the impeller speed down to about 0.7 times the engine speed), and the runner transmits motion to the rear wheels through the automatic transmission and propeller shaft.

The impeller and runner form an annular channel of circular cross-section, with a small clearance space *C* between these two members. The semicircular channels in both impeller and runner are divided into cells by a number of radial partitions or vanes *D*, as shown by that part of the diagram representing a side view. When the coupling is operating, these cells are filled with the oil fluid which is continually circulated from the transmission housing to the coupling and back, thus preventing any local heating or excessive rise in temperature.

How the Coupling Fluid Transmits Motion: When the engine is started and impeller *A* begins to rotate, the fluid within the various cells of the impeller's semicircular channel also receives a circular motion around the coupling axis. At the same time, the fluid in each cell begins to rotate around the cell itself along paths *E*, as indicated by the arrows. The power, which can be

transmitted from impeller *A* to runner *B*, depends upon the rate of this transverse rotation. But why does the fluid have such rotation and what causes the runner to be driven by the impeller?

The transverse rotation *E* is due to the unbalance between the centrifugal force of the liquid in the driving member *A* and the driven part *B*. This unbalance is due to the slower speed of B, especially during the starting period. As the speed of impeller *A* increases, runner *B* is gradually accelerated until finally it operates at practically the same speed as the driving member, except for a slight lag or slip which is said to be less than 1 per cent under the ordinary range of driving conditions. As the speeds of the driving and driven members approach each other, this centrifugal unbalance is reduced, and, consequently, the rate of transverse rotation or circulation of the fluid decreases. This is accompanied by a reduction in the torque-transmitting capacity of the coupling, but the car is now up to normal operating speed and the coupling has less work to do.

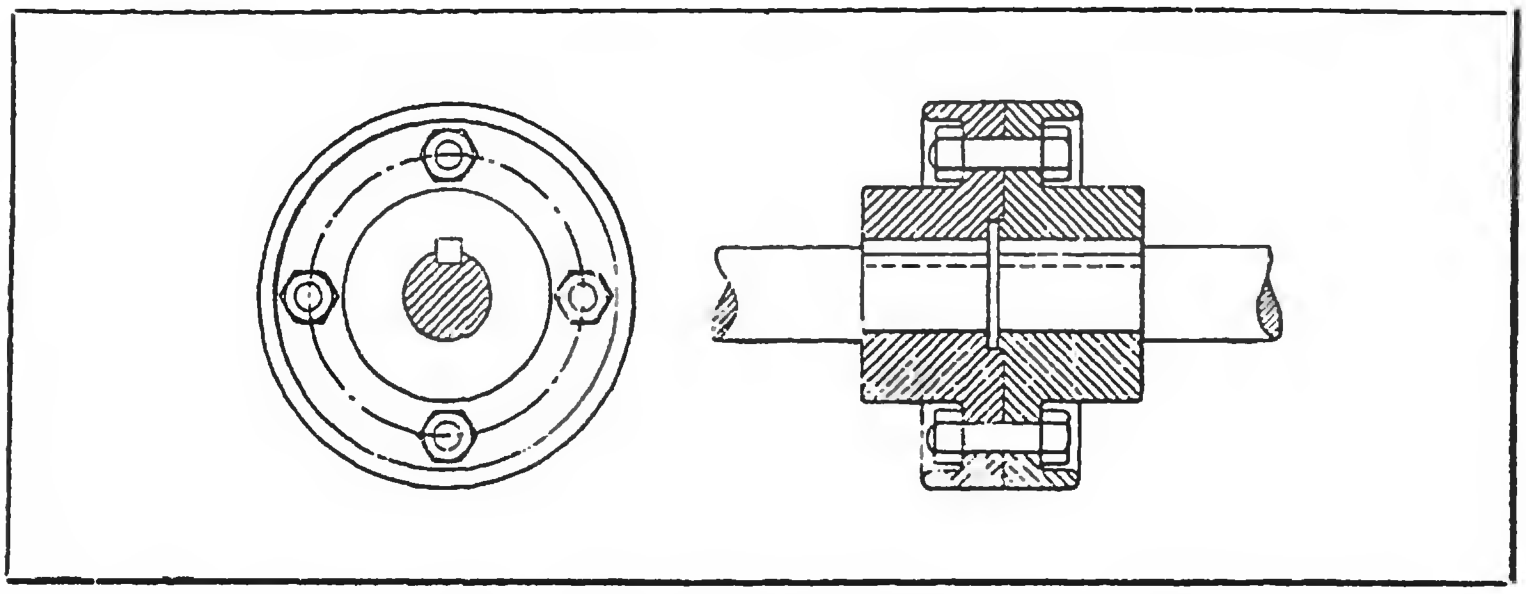
When the transmission gears are shifted to the third- and fourth-speed positions (which, like all shifting, is done automatically), the coupling transmits only about 40 per cent of its full torque capacity. When the impeller and runner are rotating together we have, then, an annular body of fluid rotating both around the coupling axis and transversely in a number of cells. This whirling mass of fluid has, of course, considerable momentum, and the two sections of the coupling are connected by this fluid body through which practically all of the energy in the driving part is transmitted to the driven member.

Incidentally, it will be noted that the central space *F*, forming a vortex around which the transverse rotation occurs, is located eccentrically relative to the annular ring formed by the two semicircular parts. This eccentric location of the vortex is for obtaining equal areas at all points in the cells. For example, the area of the opening GHJK at the inner part of the cell, where the circumferential width is less, is equal to the area LMNO at the outer part, where the circumferential width is greater, thus making it necessary to reduce the radial width.

What Happens when the Engine is Idling? When the foot is off the accelerator and the engine is idling, no motion is transmitted by the impeller to the runner. Why is this so in view of the fact that the impeller is still rotating?

It is evident, from the preceding description, that the operation of the coupling depends fundamentally upon centrifugal force which varies according to the *square* of the velocity in feet per second. Now, when the engine is idling, the transmission is in first gear and then the impeller turns at about 0.7 times the crankshaft speed. Since the square of 0.7 (representing impeller

speed) is about $\frac{1}{2}$ of the square of 1 (representing the crankshaft speed), the torque under these conditions is insufficient to start the runner and overcome the resistance of the car to motion or even to slight creeping movements. When the accelerator is pressed down and the engine speed increases, the whirling body of fluid at first impinges against the vanes of the stationary runner which, at once, begins to rotate and at an increasing rate until, finally, its vanes, like those of the impeller, are embedded in a rotating fluid body which offers high resistance to any lagging of the driven member. The entire action of the coupling



Flange Coupling

through the accelerating period is such that motion is transmitted rapidly but smoothly through the flexible fluid medium.

Couplings, Pipe. Couplings are threaded internally for receiving the ends of pipes. They are threaded either with right-hand or with right- and left-hand threads the same as nipples. "Wrought couplings" are commonly used for "wrought pipe."

Couplings, Shaft. A shaft coupling is a device for fastening together the ends of two shafts, so that the rotary motion of one causes rotary motion of the other. One of the most simple and common forms of coupling is the flange coupling (see illustration). It consists of two flanged sleeves or hubs, each of which is keyed to the end of one of the two shafts to be connected. The sleeves are held together and prevented from rotating relative to each other by bolts through the flanges as indicated. See Flexible Couplings.

Cowles Process. A method for producing aluminum alloys directly from the aluminum ore. This process was used in the early days when aluminum was very expensive, and when commercial alloys could not be produced by using the pure metal. Later, it became the practice to alloy aluminum as a metal with

other metals, but there has been a resumption of the direct production of aluminum alloys from the ore. The process consists mainly in mixing bauxite with carbon and the metal to be alloyed, and heating the mixture in an electric furnace. In the presence of the carbon, the aluminum oxide is reduced to aluminum, and this alloys directly with the other metal contained in the furnace. Alloys containing as high as 30 per cent of aluminum have been produced in this manner.

Cowper-Coles Process. The process known by this name is a galvanizing process used for covering iron and steel with metallic zinc. The process is generally known as *sherardizing* from its inventor, Mr. Sherard Cowper-Coles. The principle of the process is explained under the heading Sherardizing.

Crab. In an overhead traveling crane, the crab is the carriage moving crosswise of the span along the bridge or girder. It is from this that the load is suspended.

Cracking Process. The cracking process consists practically in distilling oils at a higher temperature than the normal boiling point. This process, as applied in producing gasoline, may also be defined as a method of splitting up the molecular structure of hydrocarbon molecules by the application of heat supplemented, ordinarily, by pressure which, in modern processes, may be several hundred pounds to the square inch. There are various modifications of the cracking process. These developments have made it possible to secure large amounts of gasoline from the heavy oils, so that the volume of light crude oil is no longer a true indication of the potential gasoline supply. According to a prominent authority, properly cracked gasolines as compared with "straight-run gasoline" obtained from a crude still, have the following advantages: (1) Generally a higher percentage of the lighter and more volatile factions; (2) better starting qualities as applied to internal combustion engines; and (3) non-detonating or "anti-knock" qualities.

When petroleum or crude oil is subjected to ordinary distillation by the application of heat, the lighter products, such as gasoline and kerosene, are distilled off to a temperature of about 300 degrees C. (572 degrees F.). For higher temperatures the hydrocarbons decompose partially so that some light products are produced and distilled along with the heavier products. If the temperature is increased sufficiently, the entire oil residue may be distilled, leaving only a variable amount of residual carbon. This property of all heavy petroleums, which results in decomposing into hydrocarbons of lower molecular weight by heating, is generally known as cracking. There are various cracking proces-

ses, such as (1) cracking in the vapor phase under *(a)* atmospheric pressure or under *(b)* high pressures of several hundred pounds to the square inch; (2) cracking in the liquid phase *(a)* with distillation either at atmospheric pressure or under high pressure, or *(b)* without distillation and with high pressure. As to the origin of the cracking process, a United States patent was granted in 1860 to Luther Atwood for the production of light hydrocarbon illuminating oils from heavy oils, paraffins, etc. The first record of pressure distillation appears to be in an English patent granted to James Young in 1865. The extremely high pressure process is covered by a United States patent granted to Benton in 1886. This patent deals with temperatures ranging from 700 to 1000 degrees F. and pressures as high as 500 pounds per square inch.

Cranes. Cranes may be classified in a number of ways, according to the principal characteristic considered.

Rotary Cranes: Rotary cranes may be divided into two main subdivisions: *jib* and *pillar* cranes. The *jib crane* consists mainly of a post or pillar from which extends a horizontal arm or jib. On this jib, a crab or trolley moves in a radial direction. *Pillar cranes* are provided with a pivot at the lower end of the column or post only, and are supported entirely from the foundation. These cranes, as a rule, are not provided with a jib and trolley, and, hence, the load is rotated in a horizontal direction along the periphery of a circle, but has no radial movement. A special type known as *pillar jib crane* is identical with the regular type of pillar crane in that it is pivoted and supported entirely at the foundation, but is provided with a jib on which a trolley moves, so that the load can be moved both in a radial and circular direction. Pillar cranes having a rotary motion only, but no trolley motion, are frequently known as *swing cranes.* The same name is applied to jib cranes if they are not provided with a trolley motion. Pillar cranes which are mounted on wheels, and so arranged that they can travel longitudinally upon rails, are known as *portable cranes* or *walking cranes.* When these portable cranes are provided with a steam engine capable of propelling them along the rails, they are known as *locomotive cranes.* In this type, steam power is also used for hoisting and moving the load.

Rectilinear Cranes: The most common of all rectilinear cranes is the *overhead traveling crane* in which there is, in addition to the lifting motion, provision for two horizontal movements at right angles to one another, so that the load can be deposited at any point within the rectangle covered by the movement of the crane. Traveling cranes consist of a bridge, generally spanning the bay of a shop or foundry, which moves longitudinally on overhead tracks provided at the end of the bridge, giving the straight-

line motion in one direction. On this bridge is mounted a trolley or crab which moves transversely along the bridge, thus giving the straight-line motion in the other direction. A *gantry crane* is similar to the overhead traveling crane except that the overhead bridge is here carried at each end by a trestle which travels on longitudinal tracks on the ground. A trolley is placed on the bridge to give the transverse motion. *Bridge cranes* have a horizontal straight-line movement in one direction only, the bridge being in a fixed position, while a trolley moves along the bridge. *Tram cranes* also have a movement in one direction only, except that in this case a very short bridge without a trolley is provided, which travels longitudinally on overhead rails.

Crankshaft Cold Saw. The crankshaft cold saw cutting-off machine is arranged for carrying two saws upon a single arbor so that two cuts may be made simultaneously when sawing out the web of a crank. These machines are built in various designs and may be used for many other operations, such as sawing out the ends of locomotive main-rods of the open-end type, and for similar work.

Crankshaft Grinding. The modern method of finishing crankshaft bearings is by grinding. The bearings may either be rough-turned in a lathe equipped for this purpose, and then be finished by grinding, or they may be ground directly from the rough drop-forging. The practice in different shops varies; ordinarily, whether or not crankshafts are rough-turned prior to grinding depends upon their size and the amount of stock to be removed. One method of finishing the pins is to use a wheel that is equal in width to the width of the bearing, so that the entire pin can be finished by feeding the wheel straight in, and without a traversing movement. Grinding machines which are used exclusively for grinding crankshafts of the type used in motors for automobiles, launches, etc., are equipped with special work-holding fixtures so arranged that the different crankpins may be aligned with the axis of the grinding machine spindle.

Creep. Creep is a time-dependent strain of solids which occurs as the result of the application of stress. When the strain occurs at a diminishing rate, it is called primary creep; when at a minimum or constant rate, secondary creep; and when at an ever-increasing rate, tertiary creep. Since the rate of creep is affected by temperature, it is a major consideration in the use of metals for elevated temperature use.

Creosoting Processes. Different methods are used for applying creosotes or other preservatives to wood poles. In the closed-tank method, the poles are placed in a large tank and steamed for from five to eight hours; a partial vacuum is then

applied, after which the creosote is run in at a temperature of from 140 to 175 degrees F. under sufficient pressure to obtain the amount of absorption desired. In the open-tank creosoting process, usually applied to the butts of poles only, the poles are placed in an inclined or vertical position with the butts immersed in the creosote, which is kept at a temperature of about 220 degrees F., for about six hours. The bath is then allowed to cool, and after it has fallen to 110 degrees F., the poles may be removed; or the poles may be changed to a cold bath (110 to 150 degrees F.) and allowed to remain for several hours. During the period of the warm bath, the air and moisture in the cells of the wood are driven out, and during the period of cooling off, the creosote enters the cells and remains there. By the open-tank method it is not possible to impregnate the wood to the same depth as with the closed-tank or pressure method. The treatment is, however, worth while, and the United States Forest Service estimates the useful life to be approximately twenty years for chestnut and western cedar, twenty-two years for northern white cedar, and twenty years for pine in the dry climate of western United States. In this connection, it should be mentioned that in poles with treated butts, it is the upper part of the poles that will decay first and govern the life of the pole. In the so-called "brush treatment," the preservative is applied with a brush. This practice is sometimes modified by pouring or spraying the preservative on the poles.

Crest of Thread. The top surface of a screw thread is known as the crest. The American standard thread has a flat crest, and the British or Whitworth standard a rounded crest.

Crest Voltmeter. This is a voltmeter depending for its indications upon the crest, that is, the maximum value of the voltage applied to its terminals.

Critical Speed of Rotating Body. If a body or disk mounted upon a shaft rotates about it, the center of gravity of the body or disk must be at the center of the shaft, if a perfect running balance is to be obtained. In most cases, however, the center of gravity of the disk will be slightly removed from the center of the shaft, owing to the difficulty of perfect balancing. Now, if the shaft and disk be rotated, the centrifugal force generated by the heavier side will be greater than that generated by the lighter side geometrically opposite to it, and the shaft will deflect toward the heavier side, causing the center of the disk to rotate in a small circle. These conditions hold true up to a comparatively high speed; but a point is eventually reached (at several thousand revolutions per minute) when momentarily there will be excessive vibration, and then the parts will run quietly

again. The speed at which this occurs is called the *critical speed* of the wheel, and the phenomenon itself is called the *settling* of the wheel. The explanation of the settling is that at this speed the axis of rotation changes, and the wheel and shaft, instead of rotating about their geometrical center, begin to rotate about an axis through their center of gravity. The shaft itself is then deflected slightly so that for every revolution its geometrical center traces a circle around the center of gravity of the rotating mass.

Critical speeds depend upon the magnitude or location of the load or loads carried by the shaft, the length of the shaft, its diameter and the kind of supporting bearings. The normal operating speed of a machine may or may not be higher than the critical speed. For instance, some steam turbines exceed the critical speed, although they do not run long enough at the critical speed for the vibrations to build up to an excessive amplitude. While a machine may run close to the critical speed, the alignment and play of the bearings, the balance and construction generally, will require extra care, resulting in a more expensive machine; moreover, while such a machine may run smoothly for a considerable time, any looseness or play that may develop later, causing a slight unbalance, will immediately set up excessive vibrations.

Critical Temperatures. The temperatures at which certain changes in the chemical condition of tool steel take place, during both heating and cooling, are referred to as the decalescence and recalescenoe or critical points, and the effect of these molecular changes is as follows: When a piece of steel is heated, it reaches a certain point at which it continues to absorb heat without appreciably rising in temperature, although its immediate surroundings may be hotter than the steel. This is the *decalescence* point. Similarly, steel cooling slowly from a high heat will, at a certain temperature, actually increase in temperature, although its surroundings may be colder. This takes place at the *recalescence* point. The recalescence point is lower than the decalescence point by anywhere from 85 to 215 degrees F., and the lower of these points does not manifest itself unless the higher one has first been fully passed. These critical points have a direct relation to the hardening of steel. Unless a temperature sufficient to reach the decalescence point is obtained, no hardening action can take place; and unless the steel is cooled suddenly before it reaches the recalescence point, no hardening can take place. The critical points vary for different kinds of steel and must be determined by tests in each case. It is the variation in the critical points that makes it necessary to heat different steels to different temperatures, for hardening.

Crochet File. Crochet files are rounding on both edges and, in a lengthwise direction, taper to a small point.

Crodon. Crodon is a trade name for a chromium plate that is claimed to be ten times as hard as nickel plate and three times as hard as cold-drawn steel. On the hardness scale, it is listed at 9 as compared to the diamond at 10. This hardness is particularly useful where resistance to rubbing action is required.

"Crodon" is not oxidized below 700 degrees F., and will protect steel from scaling at 1500 degrees F. and above. This property is being utilized in pyrometer parts, soot cleaner elements, oil burner parts, oil cracking equipment, and thermostat parts. "Crodon" is not affected by organic acids, salt water atmosphere, nitric acid, or sulphur compounds. This resistance to sulphur has proved useful in rubber molds and on oil equipment in contact with sulphur bearing oils at high temperatures. See Chromium Plating.

Croloy. A carbon-molybdenum steel with thin sheets of chromium stainless-steel welded to it. Can be hot-formed, spun, or welded as easily as unbonded plate. Useful where strength, as well as resistance to corrosion, is required.

Cross. A pipe fitting with four branches arranged in pairs, each pair on one axis, and the axes at right angles. When the outlets are otherwise arranged the fittings are branch pipes or specials.

Cross-Cut File. A type having one round edge with sides tapered toward the opposite edge. A cross-cut file is single-cut, the same as a mill bastard file of the same size.

Crossing File. Crossing or cross files have a double oval section, one side being shaped like a half-round file and the other like a cabinet file. The cut is either bastard, second-cut, or smooth.

Cross-Section Paper. Cross-section paper has horizontal and vertical ruled lines spaced the same distance apart. When this ruling is so made that the horizontal spaces are much less than the vertical, the paper is properly called *profile paper.* Cross-section paper is used for making sketches, diagrams, etc., and for free-hand work; the ruling is of great assistance in properly proportioning the parts. It is also largely used in the plotting of graphic charts and similar work. Cross-section paper is obtainable with a ruling of either 10 or 16 lines to the inch, and also with millimeter ruling. There is also cross-section paper made with 8 and 12 lines to the inch.

Cross Valve. (1) A valve fitted on a transverse pipe so as to open communication at will between two parallel lines of piping. This type is much used in connection with oil and water pumping

arrangements, especially on board ship. (2) Usually considered as an angle valve with a back outlet in the same plane as the other two openings.

Crotch. A pipe fitting that has the general shape of the letter Y. Caution should be exercised not to confuse the crotch and a Y-fitting or wye.

Crown Gear. In bevel gearing, when the pitch-cone angle of one of the gears is 90 degrees, this gear is called a *crown gear.* In this case, there is, properly speaking, no pitch cone, but rather a pitch plane. The crown gear of bevel gearing is equivalent to the rack of spur gearing.

Crown of Pulley. See Pulley Crown.

Crucible. Crucibles are pots used for melting small amounts of various metals. Their principal use in the iron and steel industry is in the manufacture of crucible or tool steel, when they generally have a capacity of from 75 to 200 pounds. Electric furnaces, however, are now used extensively for producing tool steel. The most extensive use for crucibles is in the brass industries. In many English and some American plants, the crucibles are made of a high quality of clay mixed with about 5 per cent of powdered coke. They are then known as *clay crucibles* or "white pots," but the care required in the handling of these crucibles has brought them into disfavor with most American manufacturers, who use graphite crucibles instead. Graphite crucibles can be recharged while cold, tested for thickness and cracks before each charging, and will stand rougher handling and more heats than the clay pots.

Crucible Furnace. A crucible furnace is one in which metal that is to be melted is contained in crucibles placed in the furnace. The furnace may be heated by coal, coke, gas, or oil. The use of gas or oil lessens the labor required and permits better control of the heat; it also permits heat to be localized, when desired; but carelessness in handling these fuels is more likely to destroy the crucibles than in the case of coal or coke.

Crucible Steel. Crucible Steel, also known as *tool steel, high-carbon steel,* and, in England, sometimes as *pot steel,* is made by using high-grade, low-phosphorus wrought iron and adding carbon to it. The name *crucible steel* is derived from the fact that in the final process of making this steel, it is melted in crucibles. Small pieces of wrought iron are put directly into an air-tight crucible containing the proper amount of powdered charcoal, and melted down. In this way, the proper amount of carbon is added in order to form the high-carbon steel desired. The process was first developed by Robert Huntsman, in England,

about 1740. Wrought-iron is always used in the making of crucible steel of the best grade; but cheaper grades of steel are sometimes made by using Bessemer and open-hearth soft steels; this product, however, is not as good as when wrought iron is used.

Crude Oil. See Petroleum.

Crystalline Structure of Metals. In all metals, the atoms are arranged in regular, three-dimensional patterns to form crystals. When different metals solidify, various patterns or crystal structures are formed. The crystals start to form from many points at the same time. Each crystal grows gradually from a nucleus—the atoms arranging and spacing themselves in a regular pattern (because of the forces of attraction and repulsion between the atoms)—until its boundaries interfere with the boundaries of other crystals. This interference prevents individual crystals from attaining symmetrical external shapes. However, the crystals of any particular material are identical in internal design and atomic spacing. Metallurgists call these external imperfect crystals *grains.* The over-all pattern has definite directional qualities, although adjacent crystals are seldom oriented in exactly the same direction.

The properties of a metal depend primarily on the characteristics of the atoms and the size, shape and arrangement of the crystals or grains. These factors, in turn, are dependent upon the composition of the metal, the transformation it undergoes during heat-treatment, and the amount and type of deformation to which it is subjected.

In most metals, the atoms are arranged in one of three crystalline structures or lattices: *face-centered cubic, body-centered cubic,* or *hexagonal close-packed.* Cubic crystal systems have three axes that are equal in length and perpendicular to each other. Hexagonal lattices have three axes in the same plane that are equal in length but inclined to each other at an angle of 120 degrees, plus a fourth unequal axis that is perpendicular to all three of the equal-length axes.

Body-centered cubic lattices have an atom at each corner of the cube and one in the center. This type of structure is found in both low-temperature (up to 1670 degrees F.) and high-temperature (above 2550 degrees F.) forms of iron (alpha iron and delta iron respectively), chromium, molybdenum, tantalum and tungsten.

Face-centered cubic crystals structures have an atom at each corner of the cube and one at the center of each cube face. This structure is present in the intermediate-temperature (1670 to 2550 dgrees F.) form of iron (gamma iron), and in copper, aluminum, nickel, lead, silver, platinum and gold.

Hexagonal close-packed lattices may be described as hexagonal prisms with seven atoms in both the top and bottom surfaces forming hexagonal faces with an atom at the center of each, and three atoms between these top and bottom surfaces. This type of structure is exhibited by magnesium, titanium, cobalt, zinc and cadmium.

Crystallography. See Metallography.

Crystolon. The trade name "Crystolon" is used by the Norton Company for silicon carbide, as well as for various products made of silicon carbide. See Silicon Carbide.

Cubic Equation. See Equations.

Cubic Measure. 1 cubic yard = 27 cubic feet; 1 cubic foot = 1728 cubic inches; the following measures are also used for wood and masonry; 1 cord of wood = $4 \times 4 \times 8$ feet = 128 cubic feet; 1 perch of masonry = $16\frac{1}{2} \times 1\frac{1}{2} \times 1$ foot = $24\frac{3}{4}$ cubic feet.

Cufenium. A nickel silver that has the following composition: Copper, 72 to 60 per cent; nickel, 22 to 20.5 per cent; iron, balance. This nickel silver is used in the manufacture of tableware.

Cuivriloy. An alloy used for pump rods and valve parts whose composition is as follows: copper, 25 per cent; nickel, 65 per cent; manganese, 3.8 per cent; lead, 1 per cent.

Cunic. This alloy contains 45 per cent nickel and 55 per cent copper. In the annealed condition it exhibits a tensile strength of 62,000 pounds per square inch and an elongation of 25 per cent. It is used to make thermocouples, rheostats, and shunts.

Cupaloy. Copper-chromium alloy that in the hardened condition exhibits a tensile strength of 60,000 pounds per square inch; a yield strength of 5500 pounds per square inch; an elongation of 17 per cent; a reduction in area of 60 per cent; a Brinell hardness number of 140. Its high conductivity makes it suitable for commutators, slip rings, and other electrical parts.

Cupola Bessemer Electric Process. One method of producing the "white iron" used in making malleable castings is known as the "cupola Bessemer electric process." Briefly, the iron is melted in the ordinary cupola, blown in a Bessemer converter to obtain the proper analysis, and reheated in an electric furnace preparatory to casting. This system can be used to advantage in large plants having a central melting room. The grade of malleable iron produced is excellent.

Cupola Jack Polishing Machine. A type of polishing machine known as the "cupola jack," has been extensively used. especially in the cutlery industry. The cupola jack frame consists of a cast-iron base with two cast-iron upright columns, connected by a brace at the middle. The upper end of each column is arranged to hold a removable hard-wood block in a horizontal position, with the end of the grain against the end of the shaft, and fastened in place by a set-screw. The spindle and arbor hole of the wheel are both tapered, and the polishing wheel is driven on the spindle with a tight fit. The ends of the spindle are tapered down to points, and fitted into countersunk depressions cut into the ends of the hard-wood blocks which constitute the bearings.

Cupola Malleable Iron. A malleable cast iron that contains: carbon, 3 per cent; traces of combined carbon; silicon, 0.9 per cent; manganese, 0.8 per cent; phosphorous, 0.2 per cent; iron, balance. Its uses include plumbing, pipes, and pipe fittings.

Cupolas and Air Furnaces. Two kinds of furnaces are used for melting iron preparatory to making castings, namely, cupola furnaces or "cupolas," as they are commonly called, and reverberatory or air furnaces. The cupola furnace is the most common, and is more simple in operation. In this kind of furnace, the iron and the fuel are charged together, while, in the air furnace, they are charged in separate compartments. The latter type of furnace is more frequently used in the making of malleable-iron castings. The cupola type of furnace is used in nearly all cases except when it is necessary to melt large bodies of iron, or when very large castings are to be made; the reverberatory type is preferable in the latter case, because a large body of metal can be obtained at one tapping. Ordinarily, some flux, such as limestone, is placed in the cupola when charging. This flux melts and serves the double function of first forming a slag by the combination of the lime with the silica from the charge, thus removing the silica, and also forming a protective covering for the bath of molten metal in the well of the cupola. In determining upon the various mixtures for producing different kinds of iron in a cupola, it is necessary to consider the quality and quantity of pig iron and scrap iron of various kinds, as well as the fuel and the flux that may be used.

Cupro-Nickel. Cupro-nickel is an alloy which consists of from 79 to 81 per cent of copper, the remainder being nickel, with a permissible iron content not to exceed 0.75 per cent.

Curling and Wiring Dies. Curling and wiring dies are used extensively for curling over or "wiring" the edges of pails, pans, and many other similar articles made of tinware, brass, copper,

etc. What are known as *curling dies* are also used, to some extent, for rolling small tubular parts or forming cylindrical edges on hinges, etc. The dies used in conjunction with tinware are commonly called *wiring dies,* because of their use for curling the edges of circular shaped articles around a wire, thus forming a strong, smooth edge. In many cases, the edges are curled without inserting a wire; this operation is usually referred to as "false" or "imitation" wiring, and these dies are also known as wiring dies. Curling or wiring dies for tapering parts such as milk pans, etc., have a punch which is composed of six or eight segments instead of being solid, so that it can contract when entering the tapered part.

Currency Coining Pressures. See Coining Pressures.

Custer Process. A method of producing castings in permanent molds. See Castings in Permanent Molds.

Cutter Grinder. Cutter grinding is often done on cylindrical grinding machines of the universal type, and even in the lathe, by the use of a grinding attachment, especially in small shops, but it is preferable to use a machine designed especially for this class of work. These special machines are so arranged that they may be used for grinding plain cylindrical cutters, angular cutters, end-mills, side-mills, formed cutters, reamers, circular forming tools, saws for cutting-off machines, and a variety of other tools. While the universal tool- and cutter-grinders made by different manufacturers vary more or less as to details, they are similar in their general arrangement and operate on the same general principle.

Tooth-rest for Cutter Grinding: A tooth-rest is used to support a cutter while grinding the teeth. For grinding a cylindrical cutter having helical or "spiral" teeth, the tooth-rest must remain in a fixed position relative to the grinding wheel. The tooth being ground will then slide over the tooth-rest, thus causing the cutter to turn as it moves longitudinally, so that the edge of the helical tooth is ground to a uniform distance from the center, throughout its length. For grinding a straight-fluted cutter, it is also preferable to have the tooth-rest in a fixed position relative to the wheel, unless the cutter is quite narrow, because any warping of the cutter in hardening will result in inaccurate grinding, if the tooth-rest moves with the work. The tooth-rest should be placed as close to the cutting edge of the cutter as is practicable, and bear against the *face* of the tooth being ground.

"Cutting Down." When parts are finished by buffing the term "cutting down" is applied to the operation of removing slight imperfections left either by previous polishing or by roll-

ing, stamping, etc. The relatively high finish obtained by cutting down is refined by "coloring" which gives a high luster either preparatory to plating or on surfaces after plating.

Cutting Metals with Oxidizing Flame. The principle of metal cutting by using an oxy-acetylene or other gas-burning torch, is based on the fact that, if a piece of steel or iron is brought to a red heat and a jet of pure oxygen is turned against it, the metal will be oxidized or will burn. The ordinary cutting torch consists of a heating jet using oxygen and acetylene, oxygen and hydrogen, or, in fact, any other gas which, when combined with oxygen, will produce sufficient heat. By the use of this heating jet, the metal is first brought to a sufficiently high temperature, and an auxiliary jet of pure oxygen is then turned onto the red-hot metal, when the action just referred to takes place. See Oxy-acetylene Method of Cutting Steel and Iron.

Cutting-Off Machines. In general, any machine which is designed exclusively for cutting either bar stock or structural steel may be considered as a *cutting-off machine,* but this term is usually applied by manufacturers to those machines which rotate the stock and sever it by means of a cutting-off or parting tool; machines which utilize a revolving saw for severing the material are commonly listed as *cold-saw cutting-off machines,* or simply as cold saws. The term "cold" is used in this connection to indicate that the machine is intended for cutting unheated stock. Among other machines used for cutting off stock, which may properly be inserted under the general classification of cutting-off machines, are hacksaw machines, metal-cutting band saws, abrasive wheel cutting-off machines, and the friction saw. See Cold-Saw Cutting-off Machines.

Cutting Off Stock with Abrasive Wheels. Abrasive wheels formerly were used for cutting off metal only when the material to be cut was such that steel saws could not be used. Today not only is metal bar stock and tubing cut economically with abrasive wheels, but such materials as plastics, glass tubing, porcelain, etc., are being cut—materials that formerly could only be handled by slower and more costly methods. Furthermore, the metals to be cut do not have to be annealed for the cutting-off operation; hence hardened tool steels, and even Stellite, can be cut without injury to the tools.

Wheels Used: There are three types of organic bonds used in the manufacture of abrasive cutting-off wheels—shellac, rubber, and resinoid. The shellac bond produces a soft wheel, suitable for cutting tool steels. Highly heat-sensitive high-carbon and high-

speed steels for lathe and planer tool bits, for example, are readily cut without discoloration.

The rubber bond makes practical the manufacture of wheels as thin as 0.005 to 0.006 inch. Such wheels are used for slotting pen nibs. Wheels 0.020 or 0.025 inch thick are used for cutting tungsten rod. Glass tubing is being cut without chipping by wheels from 0.030 to 0.062 inch in thickness. Rubber-bonded wheels are generally used for wet and submerged cutting operations and for certain high-speed cutting jobs where a somewhat flexible wheel is required.

Resinoid-bonded wheels are recommended for dry cutting where "burn" and burring are not objectionable and where the area of cross-section is relatively large. Carbon, plastics, and tile are generally cut wet with resinoid-bonded wheels. With the introduction of resinoid bonds, wheel speeds were gradually increased from 9000 to 16,000 surface feet per minute, corresponding gains in cutting-off time being obtained.

Types of Abrasive Cutting Machines: There are four general classifications of abrasive cutting machines: (1) High-speed machines; (2) low-speed machines; (3) wet and submerged machines; and (4) portable machines.

The high-speed machine must, of necessity, be designed for safe operation of high-speed abrasive wheels. The machine bearings must have no side play, and the movement in the plane of the wheel toward the work must be positive. Wheel balance, thickness variation, and warping or dishing are controlled in the wheel manufacture within narrow limits.

The low-speed cutting machines include a variety of types, from specially designed bench and floor stands with fixtures to makeshift or revamped equipment. The recommended operating speeds vary from 9000 to 10,000 surface feet per minute.

The wet and submerged types of cutting machines actually belong in the low-speed group; but these machines are designed with the rigidity of high-speed machines. Considerable economy has been obtained in the cutting of tubing by cutting wet at low speed, using rubber-bonded wheels. Metallographic specimens are also cut wet.

In the submerged method, the wheel speed is, in some instances, lower than that of the low-speed machines—sometimes as low as 1200 revolutions per minute, using 12- and 14-inch diameter wheels. Higher speeds tend to make the wheel create a trough in the coolant, and thereby defeat the purpose of this method of cutting. Chipping, burning, and excessive burring will be the result. These machines operate with the work entirely submerged in water or other coolant, and are principally used for cutting glass tubing, porcelain tubes, light-wall metal tubing,

and small plastics. Wheels for wet abrasive cutting machines are furnished as thin as 3/32 inch for 16-inch diameter wheels.

Portable cutting machines generally use wheels from 6 to 12 inches in diameter, operating at from 2000 to 2500 revolutions per minute. Machines of this type are used by quarries, building contractors, etc., and also in small metal-working shops.

Cutting Oils and Compounds. Oil or cutting compound is delivered to a metal-cutting tool in order to increase production, to give longer life to the tool, and in some cases to secure a better finish on the work. The functions of an oil or cutting compound may be presented under five heads: (1) To cool the work and cutter. (2) To wash away chips. (3) To lubricate the bearing formed between the chip and lip of the cutting tool. (4) To enable the cutting tool to produce a good finish. (5) To protect the finished product from rust and corrosion.

The cooling action is the most important function. During the performance of any machining operation generation of heat is due to friction between the tool and work, and to distortion of the chips. This results in raising the temperature of both the cutting tool and the work; and if provision is not made for the removal of this heat, the temperature may become so excessive that the cutting edge of the tool breaks down. Another important consideration is the possibility of having the work raised in temperature so that it expands considerably during the machining operation, and while the tools may continue to produce parts of the required size when measured at this high temperature, the work will contract on cooling so that it will be under size. A great variety of oils and cutting compounds are used for metal-cutting tools.

Cutting Saw of Electric Arc Type. The electric arc saw is designed to cut iron, steel, and any ferrous or non-ferrous alloy, as well as tungsten carbide. This machine operates on a low-voltage current applied across the arc. The actual saw unit consists of a soft alloy steel disk provided with a large number of small straight teeth on its outer edge. Cuts are made by means of a controlled electric arc that "leaps" ahead of the saw and brings the metal along the kerf lines to a molten or plastic condition. The saw disk does no actual cutting, but serves to sweep the molten metal from between the kerf lines and acts as an electrode from which the heat generating arc "jumps" to the work. The real function of the saw is to give impulse to an oscillation of the current through a lengthening and shortening of the arc which stabilizes and directs the path of the arc to such an extent that side arcing is eliminated. The arc thus controlled travels in a path a few thousandths of an inch wider than the width of the saw.

Cyanide. Cyanide is a salt of prussic or hydrocyanic acid. The most important of the cyanides commercially is *potassium cyanide,* which is used in the "cyanide process" of gold extraction, and in the mechanical industries as a heating bath for hardening steel, and as a means for casehardening. Cyanide of potassium as a heating bath for heating steel cutting tools, dies, etc., has been utilized in preference to lead heating baths. Cyanide of potassium must be used carefully, because it is a violent poison. The fumes are very injurious and the crucible containing it must be covered with a hood connecting with a chimney or ventilating shaft. The bath is extensively used for hardening when an ornamental color effect is desired on the hardened parts.

Cyanide Coloring of Steel. In using cyanide to color hardened steel, the work is immersed in the bath, brought up to its hardening temperature, and then transferred to a water bath for quenching. At the moment of quenching, the cyanide causes the quenching bath to become violently agitated as a result of the rapid transformation of small quantities of water to steam; this steam and the air drawn into the water by the agitation, partially oxidizes the steel in spots, giving the variegated colors, which are simply intensified tempering colors. While in the cyanide bath the steel is protected from the oxidizing effect of the air and it is also protected during its transfer to the quenching bath by a liquid film of cyanide which adheres to the steel and thus prevents the air from coming in contact with the work. The use of a cyanide pot for complete immersion of the work is more satisfactory than the method of sprinkling powdered cyanide on the work while it is being heated. Fair results can often be secured by the latter method, but more often the cyanide burns off and the steel is oxidized beyond the temper colors of, say, 650 degrees F. To increase the mosaic effect and obtain brighter colors, hardeners effectively employ either or both of the following methods: (1) Pass the hot steel through a water spray when transferring from the cyanide to the quenching bath. (2) Have a stream of air bubbling through the water in the quenching tank.

Cyanide Hardening. When low-carbon steel requires a very hard outer surface but does not need high shock-resisting qualities, the cyanide hardening process may be employed to produce what is known as superficial hardness. The superficial hardening is the result of carburizing a very thin outer skin which may be only a few thousandths inch thick. The preferable method of cyanide hardening is by immersing the steel in a bath of liquid potassium cyanide or some other mixture containing cyanogen as a base. This carburizing process is, of course, fol-

lowed by quenching. Another method of cyanide hardening is to sprinkle over the surface of the steel a pulverized cyanide salt which is melted as the steel is heated to the proper temperature. Referring to the first method, which is conducive to greater uniformity in carburizing as well as increased efficiency, the potassium cyanide salt is melted in a pot furnace and the temperature of the molten bath should be slightly over the upper critical range of the salt—say 1550 to 1600 degrees F. The steel ordinarily is immersed for 10 or 15 minutes and it is quenched usually in lime water to neutralize the cyanide remaining on the steel. The pot furnace used should be equipped with a hood for carrying off the fumes as cyanogen compounds are deadly poisonous.

Cyanide-of-Potassium Bath. Cyanide of potassium may be used in preference to lead, for heating steel cutting tools, dies, etc. Sodium cyanide, however, costs less than potassium cyanide and is generally used. When cyanide is used, the parts should be suspended from the side of the crucible by means of wires or wire cloth baskets, to prevent them from sinking to the bottom. Steel will not sink in a lead bath, as lead has a higher specific gravity than steel. Cyanide of potassium should be carefully used, as it is a violent poison. The fumes are very injurious, and the crucible should be enclosed with a hood connecting with a chimney or ventilating shaft. This bath may be used for hardening in gun shops, in order to harden parts and at the same time secure ornamental color effects.

Cycle, Alternating Current. "Cycle," as applied to alternating current, refers to that period of time in which the current builds up from zero to its maximum, then drops gradually back to zero, and passes through the same increase and decrease in the opposite direction. Thus there are two alternations for each cycle. By the "number of cycles," that is, 60, 50, or 25, is meant the number of complete cycles per second. In other words, for a 60-cycle line there are $60 \times 60 \times 2 = 7200$ alternations per minute.

Cycles, Internal Combustion Engines. Engines of the internal combustion type or those which derive energy from gas, gasoline and other oils, may be divided into two general classes. One class includes engines which operate on the *four-stroke cycle* or the Otto cycle, and the other class includes the *two-stroke cycle* engines. The four-stroke cycle consists of a suction stroke which serves to draw the mixture of air and fuel into the cylinder; a compression stroke during which the charge of air and fuel is compressed into the clearance space; the expansion stroke which

follows the ignition of the charge or the explosion of the gaseous mixture; and finally the exhaust stroke which expels the burned charge from the cylinder. Since four piston strokes are thus required to complete one cycle, there is one explosion during two revolutions of the crankshaft; consequently, the flywheel is depended upon to store enough energy to keep the engine moving at a fairly uniform rate during the complete cycle. The two-stroke cycle engines of the ordinary type are so designed that an explosion occurs every revolution of the crank.

Cycloid. The cycloid is a geometrical curve which is produced by a point located on the periphery of a circle when the circle rolls along a straight line. A curve known as an *epicycloid* is formed by a point on the circumference of a circle which rolls on the outside of another circle. A *hypocycloid* is produced by a point on the circumference of a circle which rolls along the inside of the circumference of a larger circle.

Cycloidal Gear Teeth. When the outline of gear teeth is formed by an epicycloid above the pitch circle and by a hypocycloid below the pitch circle, the gear teeth so formed are generally known as *cycloidal gear teeth.* The most important point in favor of the cycloidal system of gearing is the freedom from interference of the teeth, but this advantage is considerably modified by the fact that, in order that cycloidal gears shall run properly together, the pitch circle of the two gears must tangent each other; that is, the center distance between the two gears must be very accurate. With involute gears, the distance between the centers may be varied somewhat without affecting the smoothness of the action. Cycloidal gear teeth are seldom used at the present time. Cast gears were in the past always made with this system of teeth; now for cut gearing, and also for a large proportion of cast gearing, the involute system has replaced the cycloidal.

Cylinder-Boring Machine Classification. The general methods of boring and finishing cylinders differ in regard to the method of presenting the tool to the work and of obtaining the necessary rotating and feeding movements. For instance, the tool may be held stationary except for the feeding movement, while the cylinder is revolved, or this order may be reversed. In some cases, the tool is given both a rotating and feeding movement, the exact arrangement depending upon the type or design of the machine. All cylinder boring machines may be included in one of three general classes designated as (1) machines designed exclusively for cylinder boring; (2) machines which may be adapted for cylinder boring but are intended for other opera-

tions as well; (3) portable machines or boring-bars which are applied to the cylinder to be bored. The first class includes both horizontal and vertical designs which vary considerably in regard to the general arrangement of the various details. The second class of machines mentioned which are not designed primarily for cylinder boring, but which are adaptable to it, includes such machines as engine lathes, turret lathes, and horizontal and vertical boring machines. The third class includes the various forms of portable boring-bars which have their own feeding mechanism and (with the exception of hand-operated tools for truing small cylinders) are designed for a power drive, either by belt or by a direct-connected motor. The cylinder boring machines of vertical design have been extensively used for automobile engine cylinders.

Cylinder Grinder, Planetary Type. The planetary or eccentric-head type of grinder is so arranged that the cylinder casting does not revolve while being ground. The grinding wheel, as it revolves rapidly about its own axis, is given a relatively slow circular or planetary motion, so that it is carried around the wall of the cylinder. At the same time, the cylinder, which is mounted on a carriage or slide of the machine, is given a lengthwise feeding movement which, for each complete circular movement of the wheel around the cylinder wall, is somewhat less than the width of the grinding wheel. The spindle-head of the grinding machine is so arranged that the eccentricity of the wheel-spindle or the diameter of the circular path it follows can be varied for grinding different diameters.

Cylinder Strength Formula. See Barlow's Formula.

Cylindrical Grinding Machines. The cylindrical grinder was first made in the early sixties as a grinding lathe by the Brown & Sharpe Mfg. Co., for the grinding of sewing machine parts. The regular manufacture of "grinding lathes" began in 1864, parts of 14-inch Putnam lathes being modified to permit mounting a grinding wheel on the carriage as well as an automatic feeding and reversing attachment and a dead center pulley.

Machines of the cylindrical type are intended primarily for grinding cylindrical parts, although they can also be used for taper work and other grinding operations, the extent of which may be increased considerably by the use of auxiliary equipment. For ordinary cylindrical grinding, the work is held between the centers of the machine, and it is rotated at a comparatively slow speed, while the grinding is done by a rapidly revolving grinding wheel. The machine is usually arranged so that the work is given a lateral feeding movement, in order that

the wheel may cover the entire surface to be ground; some machines, however, are so constructed that the work rotates in one position and the wheel is given a traversing movement. Cylindrical grinding machines are equipped with a mechanism which enables the grinding wheel to be fed in automatically toward the work for taking successive cuts.

Cylindrical grinding machines, like milling machines, are divided into two general classes, known as *plain* and *universal* types. The wheel slide of a universal machine can be swiveled with relation to the travel of the table; the headstock can also be set at an angle, and provision is made for revolving the headstock spindle for grinding parts that are held in a chuck or otherwise. With a plain machine, the wheel slide is permanently set at right angles to the table travel and the headstock cannot be swiveled.

D

Dado Joint. This type of joint is used in patternmaking and in other branches of woodworking, for securing the ends of ribs or partitions to the sides of boxes or frames. The rabbet-dado joint is a modified form for corners, which resists both inward and outward pressure. See Joints Used in Patternmaking.

Dalton's Law. A chemical law, known as Dalton's law, states that when two chemical elements form more than one compound with each other, the weights of the one which unite with a fixed weight of another bear a simple ratio to each other. For example, carbon unites with oxygen in two proportions, as carbon monoxide and as carbon dioxide. The latter compound contains the same amount of carbon, but exactly twice as much oxygen as the former. Nitrogen combines with oxygen in five compounds containing respectively two, three, four, and five times as much oxygen as does the first compound, the amount of nitrogen remaining the same. This law is also known as the "Law of Multiple Proportions."

Damascus Steel. A characteristic feature of damascene or Damascus steel is its surface patterns which vary with the carbon content and are either in the form of wavy parallel stripes or mottled patterns. This steel represents an early development in steel making, as it was imported during the Middle Ages to Western Europe through Syria and Palestine, and is known also as Indian steel and bulat. The old Indian method of producing real damascene steel consists in using a pure ore and the best grade of charcoal. The Persian practice is to use soft iron bars and charcoal and plumbago to supply the carbon; and a third method consists of a certain heat-treatment which resembles a prolonged tempering. One investigator has concluded that the carbon, irregularly dispersed in the metal and forming two distinct combinations, is what causes the damask or characteristic pattern and that the slower the cooling the larger the veins will be.

The general but erroneous opinion is that the variegated surface of Oriental swords resulted from their being composed of a compound of bars and wires of iron and steel, welded and wrought together and then twisted by forging in different directions. A dagger blade of good damascene steel, properly hardened, cannot be broken by bending, but can be bent to such an extent that it loses its elasticity. When bent in the usual fashion,

the blade flies back and retains its original shape. When bent more forcibly, the blade may not spring back again, but does not lose its original elasticity after straightening again. An imitation of Damascus steel can be obtained by etching the surface of the steel blade with acids, the parts which are not to be attacked by the acid being protected by a "resist."

Damping. The pointer of an indicating instrument of the type having a hand and graduated scale should preferably come quickly to its correct position on the scale, without oscillating to and fro. This enables readings to be taken with rapidity, and insures that the indications of the instrument follow correctly the fluctuations in the quantity being measured. To overcome the swinging of the moving parts first to one side and then to the other, of the point of rest, it is customary in the construction of electrical measuring instruments, to provide some form of "damping." The retarding force so utilized is produced by the motion of the parts, being zero when there is no motion, but increasing rapidly as the speed of the parts increases. Thus there is no hindrance to the moving element taking its correct position of equality between actuating and counter forces, but violent motions or oscillations are effectively retarded, and the instrument is said to be "dead beat" or "aperiodic."

Three forms of damping are in common use: 1. Air friction. 2. Electrical eddy-currents. 3. Liquid friction. Forms (1) and (3) are similar, in that both employ vanes or surfaces the motions of which are retarded according to the laws of fluid friction. *Air damping,* using light vanes or pistons swinging with small clearances in their enclosing boxes, is widely used for all classes of instruments. *Liquid damping* has more limited application; it is used in certain stationary instruments, and particularly where the parts are heavy and the forces great. In *eddy-current damping,* a conductor which is part of the moving system is arranged to move in the field of a magnet. The action of the resulting eddy-currents in the conductor upon the magnet provides the retarding or damping force. This form of damping is universally used in moving-coil permanent magnet instruments, where the conductor is readily supplied by winding the moving coil on a metal form, the magnet being already present. It is extensively used upon other types of instruments in the form of a metal sector swinging between the poles of a permanent magnet. Its most extensive application is in watt-hour meters, where a disk rotates in the air-gap between the poles of one or more permanent magnets. In this case, however, the damping force is utilized as the counter-force or control, since it fulfills the requirement of being directly proportional in amount to the speed of rotation.

Daniell Cell. The Daniell cell is one of the well-known forms of wet electric batteries. It has a zinc anode and copper cathode with zinc sulphate for the electrode, although sometimes dilute sulphuric acid is used, and copper sulphate for the depolarizer. In its original form, it consists of a glass jar in which is placed the zinc cylinder, and within this a porous cup containing the copper-sulphate solution and the copper cathode. The rest of the jar is filled with zinc-sulphate solution. The E.M.F. depends upon the density of the copper-sulphate solution and on the amount of zinc sulphate present in the dilute sulphuric acid. It is usually only from 1.07 to 1.14 volt.

Darby Process. A method for recarburizing the charge in a Bessemer converter. In this process the carbon is added by throwing anthracite or coke into the casting ladle as the steel is poured into it. The coke or anthracite is placed in large paper bags which have been carefully weighed so that each bag will give from 0.01 to 0.02 per cent of carbon to the steel.

Darcy's Formula. Darcy's formula for the flow of steam in pipes gives the cubic feet of steam per minute which will flow through a pipe when the initial pressure, the terminal pressure, the diameter of the pipe, the weight per cubic foot of the steam at the initial pressure, and the length of the pipe, are known. The formula is of the following form:

$$Q = c\sqrt{\frac{(P - p)\,d^5}{wL}},$$

in which: Q = cubic feet of steam passing through pipe per minute; c = constant found from the accompanying table; P = initial pressure, in pounds per square inch; p = terminal pressure, in pounds per square inch; d = diameter of pipe, in inches;

Table of Constants and Fifth Powers

Diameter of Pipe, Inches	Value of Constant c	Fifth Power of d	Diameter of Pipe, Inches	Value of Constant c	Fifth Power of d
1	45.3	1	5	58.4	3,125
1½	48.5	6	6	59.5	7,776
2	52.7	32	7	60.1	16,807
2½	54.3	97	8	60.7	32,768
3	56.1	243	9	61.2	59,049
3½	57.1	523	10	61.8	100,000
4	57.8	1024	—	—	—

$w =$ weight per cubic foot of steam at the initial pressure P; and $L =$ length of pipe, in feet.

The table which gives the value of the constant c, also contains the fifth power of d, as used in the formula, for certain diameters of pipe.

Dardelet Thread. The Dardelet patented self-locking thread is designed to resist vibrations and remain tight without auxiliary locking devices. The locking surfaces are the tapered root of the bolt thread and the tapered crest of the nut thread. The nut is free to turn until seated tightly against a resisting surface, thus causing it to shift from the free position (indicated by dotted lines) to the locking position. The locking is due to a wedging action between the tapered crest of the nut thread and the tapered root or binding surface of the bolt thread. This self-locking thread is also applied to set-screws and cap-screws. The holes must, of course, be threaded with Dardelet taps. The abutment sides of the Dardelet thread carry the major part of the tensile load. The nut is unlocked simply by turning it backward with a wrench. The Dardelet thread can either be cut or rolled, using standard equipment provided with tools, taps, dies, or rolls made to suit the Dardelet thread profile. The included thread angle is 29 degrees; depth $E = 0.3\ P$; maximum axial movement $= 0.28\ P$. The major internal thread diameter (standard series) equals major external thread diameter plus 0.003 inch except for ¼-inch size which is plus 0.002 inch. The width of both external and internal threads at pitch line equals $0.36\ P$.

Dead Beat. When the pointer or indicating hand of an electrical or other measuring instrument moves to position without violent and prolonged oscillations, the instrument is said to be "dead beat" or aperiodic. The excessive oscillations are prevented by some method of damping. See Damping.

Dead Center. This term as applied to machine tools relates to the stationary center on which work revolves while being machined. In a lathe, the dead center is that mounted in the tailstock. In grinding machines, both centers frequently are stationary or dead.

An engine is said to be on the "dead center" when the piston is at one end of the stroke, the crank, connecting-rod, and piston-rod being in a straight line. The name "dead center" is derived from the fact that, when the crank and piston are at the end of the stroke, the steam pressure does not exert a turning force upon the crank, the thrust of the piston being transmitted directly to the shaft and bearings.

Decalescence Point. The decalescence point is the temperature at which a decided change in the internal condition of steel takes place, and above which steel must be heated in order that it may be properly hardened by quenching. Generally speaking, the decalescence point of any carbon steel marks the correct quenching temperature of that particular steel. When steel is heated, it reaches a point where it will absorb heat for a brief period without a rise in the degree of temperature of the steel; this point is the decalescence point. As soon as this point has been reached, the steel is ready to be removed from the source of heat; the quenching then checks or traps the steel in the condition into which it has been changed at this temperature. The decalescence point is not the same for all steels, but occurs for most carbon steels at temperatures between 1350 and 1450 degrees F.

Deceleration. Deceleration or de-acceleration is the rate of change in the velocity of a moving body when the velocity is decreasing; or, specifically, the decrease in velocity of a body during a very short interval of time, usually one second.

Decibel. The decibel is a unit established to indicate the relative intensities of different noises or sounds. When bodies vibrate, sound waves are transmitted through the air, thus causing sound or noise. These sound waves vary in length and frequency. The latter term indicates the number of waves transmitted per second. The velocity of sound, which is about 1100 feet per second through the air, is practically constant regardless of the frequency or wave length. Velocity is affected slightly by atmospheric temperature changes, there being a variation of about 5 per cent in the ordinary temperature range. The velocity of sound, when transmitted through solids, is very much greater than in passage through the atmosphere. For example, the velocity through steel is about 17,000 feet per second, or over fifteen times the velocity through the air.

Noise or sound intensity may be measured directly in decibels by using a *sound level meter.* A general idea of the relation between the decibel scale and everyday sounds may be obtained from the following comparisons: A whisper is equivalent to about 35 decibels; the noise in an average business office, 65 decibels; the noise made by a passing automobile at 15 to 50 feet, from 75 to 85 decibels; the noise equivalent to heavy street traffic in a city, 105 decibels; and the noise of a subway express train passing through a station, about 115 decibels.

Decking. In a belt conveyor installation, the protection provided for preventing the material being transported from falling onto the reverse side of the lower returning belt is called "deck-

ing." If gritty material falls on the reverse side of the belt it will become imbedded as the belt passes over the pulleys, and will gradually wear and destroy the belt.

Decomposition. In chemistry, a chemical reaction in which a compound is divided into two or more products.

Dedendum. Dedendum is the distance from the pitch circle of a gear to the bottom of the tooth space or to the root circle. The *dedendum* is equal to the *addendum* plus the clearance. The addendum of full-depth teeth is equal to 1 divided by the diametral pitch, and the clearance is equal to 0.157 divided by the diametral pitch; hence the dedendum, or depth of the tooth below the pitch-line, is always equal to 1.157 ÷ diametral pitch. In bevel gearing, the dedendum is the depth of the tooth space below the pitch-line at the large end of the tooth.

Deep-Freezing of Steel. See Sub-Zero Treatment of Steel.

Deflocculated Graphite. Deflocculated graphite is a lubricant consisting of finely divided graphite suspended in water or oil, by means of a small quantity of gallotannic acid, which, when added to the water, prevents the graphite from settling to the bottom. The graphite seems to entirely dissolve in the water, under these conditions. The black liquid will easily pass through the finest filter paper. Severe tests have demonstrated that it is a satisfactory lubricant. Deflocculated graphite also possesses the remarkable power of preventing rust or corrosion of iron or steel. The graphite appears to entirely neutralize the effect of the water in which it is suspended. Light and thin oils, when used in conjunction with deflocculated graphite, can be used in place of the heavy and expensive lubricating oils. The lasting qualities of these graphite lubricants are greater than the oil lubricants which they often displace.

Degree. The degree is the unit of angular measurements and is equal to 1/360 of the circumference of a circle. One degree is subdivided into 60 minutes, and 1 minute into 60 seconds. The degree is also the unit of measurement for temperature, thermometers being graduated in degrees. The value of 1 degree of temperature varies on the different thermometer scales. Electrical degrees are referred to in connection with alternating electric currents. One complete cycle—that is one complete set of positive and negative values of an alternating current—is equal to 360 electrical degrees; hence, an electrical degree is 1/360 of a cycle.

Delta Connections. In a three-phase alternating-current system, the generators and motors are designed with three windings or phases which are either connected in mesh or delta connection,

connected to the en dof another winding, all three forming a Greek letter "delta" (△), or connected in star, which is then called a Y-connection, because the diagram of the three windings forms a "Y." In the delta connection each end of a winding is connected to the end of another winding, all three forming a closed circuit. In the star connection, one end of each winding is connected to a common point.

Delta Metal. Delta metal is an alloy consisting mainly of copper and zinc with small percentages of iron and tin. The percentages of its composition vary somewhat, but it is composed generally of about 60 per cent of copper, 36 per cent of zinc, 2 per cent of iron, and 2 per cent of tin.

Demagnetizer. Hardened tool-steel parts that have been held on a magnetic chuck become permanently magnetized, and this is also true, in a slight degree, of cast-iron parts. This residual magnetism is objectionable for some classes of work, and a device known as a "demagnetizer" is used for removing it. This apparatus consists of an iron base upon which is mounted a wooden box containing a revolving member in the form of a magnet held in a rotating framework; a pulley for rotating the demagnetizer is provided. The cover of this apparatus is detachable and supports a mass of laminated sheet-iron plates which are in contact with two metal plates attached to the top cover. After the apparatus is set in motion, all traces of magnetism may be removed from the work by simply moving it several times in and out of contact with these metal plates. The phenomenon of demagnetizing may be briefly explained as follows: The iron plates at the top of the apparatus represent the poles of a magnet in which the polarity is rapidly reversing. This reversal of polarity is transmitted to the work in contact with the plates. At the moment of reversal, however, there is a neutral point in which, for an instant, there is no magnetism. In removing the work out of a strong magnetic field to a weaker one (by lifting it away from the apparatus), it has moved a certain distance during the time that the magnet is neutral, and, when next charged, being in a weaker field, it does not take as strong a charge as before; thus, by a repetition of this movement, the magnetism is finally removed entirely.

Demand Meter. A demand meter records or indicates the maximum average electric power load over any specified time interval, or the average load over a number of equal time intervals. It is frequently installed where there is apt to be a peak demand for power quite in excess of the ordinary load. Its readings then serve as a basis for a demand charge which is in addition to the customary charge for actual power utilized. Since

a power company's electric generating and distributing equipment must always be adequate to meet peak demands, a demand charge is made in order to equitably distribute the cost of maintaining and operating such equipment.

Density. The density of any solid, fluid or gaseous substance is the mass of that substance per unit volume. If weight is used in the ordinary sense as being equivalent to mass, then the density may be defined as the weight per unit volume. It is then evident that the numerical value of the density of a substance depends upon the unit in which the mass or weight is expressed, and also upon the unit of volume used. In engineering and scientific work, however, the density of a substance is generally expressed in grams per cubic centimeter, without naming the units, because, when so expressed, the density will, for all practical purposes, be equal to the specific gravity.

Deoxidized Bronze. An alloy containing copper and tin as its chief constituents, generally being composed as follows: Copper, 82.5 per cent; tin, 12 per cent; zinc, 3.4 per cent; lead, 2 per cent; and iron, 0.1 per cent.

Depolarizer. As a result of chemical action in a primary cell, hydrogen may be released and form a film over the surface of the cathode. Hydrogen is a non-conductor, so that a layer of it on the cathode would prevent the passage of the current; a cell in that condition is said to be polarized. Polarization decreases the electromotive force of the cell and may entirely prevent its useful operation. Any substance that, when placed in the electrolyte or on the electrodes, will partly or entirely prevent this collection of hydrogen on the cathode is called a depolarizer. Thus, manganese oxide or some other metallic oxide is used as a depolarizer to release oxygen which combines with the hydrogen to form harmless water. See also Polarization.

Depreciation of Mechanical Equipment. The depreciation or reduction in value of mechanical apparatus is estimated in advance in order to determine what funds should be set aside periodically to provide ultimately for the purchase of new equipment. Depreciation percentages, even for the same types of equipment, vary considerably because they are affected by certain variable factors, such, for example, as (1) extent of wear resulting from use or location of equipment; (2) obsolescence or reduction in value due to development of more efficient apparatus (in this connection either a reduction or an increase in replacement value of new apparatus may have to be considered); (3) care of equipment, both as regards operating conditions and maintenance or repairs. These factors vary widely for different

classes of equipment. Certain types of machines and tools, for example, depreciate in value as the result of wear only; whereas other types become obsolete and are uneconomical to use because an improved design or type has been developed. The following depreciation rates, all which are given as percentages of the original cost, have been obtained from various sources. The extreme variations recommended by various authorities are given to indicate the fluctuations under different conditions. The average percentages, together with the number of sources upon which the averages are based, are also included.

Belting: Main belts, range 5 to 25 per cent; average from eleven sources, 12 per cent. Machine belts, 25 to 50 per cent.

Motors: Range 4 to 10 per cent; average from twelve sources, 7 per cent.

Engines, Reciprocating Steam: Range 4 to 10 per cent; average from thirteen sources, 6 per cent. *Engines, Turbine Type:* Range 3 to 7 per cent; average from thirteen sources, 5 per cent. *Engines, Gas:* Range 5 to 10 per cent; average from eight sources, 7 per cent.

Boilers: Range 4 to 10 per cent; average from eighteen sources, 6 per cent.

Pumps: Range 3½ to 8 per cent; average from nine sources, 5 per cent.

Hoists: Range 7 to 12 per cent.

Cranes: Range 2 to 10 per cent; average from eight sources, 6 per cent.

Machine Tools: Common range for standard types subject to normal usage, 5 to 10 per cent. For manufacturing types or special designs used continuously, the range may vary from 15 to 30 per cent. Each type of machine tool must be considered separately because of the wide variety of operating conditions and also on account of the numerous developments in the machine tool industry which cannot be predetermined.

Machinery in General: Range 5 to 13 per cent; average from eight sources, 9 per cent.

Dies: Range 25 to 50 per cent; average from four sources, 40 per cent. The cost of tools of this class, when made for a particular order, should be charged to that order.

Hammers, Drop and Steam: 10 per cent.

Patterns: Range 20 to 100 per cent; average from six sources, 65 per cent. Metal patterns have a lower depreciation rate than wood patterns, but in any case when patterns are for a particular job, the entire cost should be charged to that job.

The foregoing figures are intended chiefly as a general guide.

Descaling Apparatus. An oxy-acetylene type of descaling apparatus is used for removing scale or similar accumulations from iron and steel by rapidly heating the deposits with multi-flame tips. This heating causes the scale to crack off as a result of the difference in the rate of expansion between the scale and the base metal. The process is adapted for removing scale from ingots, billets, and slabs to expose seams and defects for inspection prior to scarfing or chipping. It can also be used for removing scale from forgings and steel castings prior to machining, as well as from steel castings after annealing.

Another important function of the apparatus is the driving out of the occluded moisture from within and beneath the surface scale of structural steel and plate by rapidly heating the surface with the high-temperaure flames, leaving a warmed surface for painting. Immediately after the flame application, the surface is wire-brushed and swept clean of loosened scale particles and dust. The painting is then done before recondensation of moisture occurs. An ideal paint base is thus provided and the danger of further loosening of the protective mill-scale through weathering is minimized.

Design Patent. In the language of patent law, the word "design" does not mean the physical arrangement of the parts of a machine, but refers solely to its ornamental appearance. A design patent gives its inventor a monopoly to the exterior appearance of the thing patented.

A design patent may be obtained by any person who has invented any new, original, and ornamental design for any article intended to be manufactured, but the interior views, or other parts that will not be seen when the apparatus actually is performing its service, cannot be protected. A simple legal form, together with the required drawing, comprises a complete application for a design patent. See Patent on Design.

Detinning. The recovering of tin from tin scrap, old tin cans, etc., is known as *detinning*. Two methods are in use for this purpose. One method is based upon purely chemical means, the tin being converted into tin tetrachloride by treating it with dry chlorine. The other method is electrolytic, the tin being dissolved and deposited in the metallic state.

Diagrams. Diagrams are used for obtaining unknown factors in a problem without carrying out the calculations required in figures; they may also be used for checking the results of calculations made by figures. The results are obtained by simply following the lines in the diagram in a certain manner, which may be different for different diagrams. Each diagram covers a large

number of problems of the same type, but for different kinds of problems other diagrams must be devised.

Practically all engineering information that can be presented in tabular form can be arranged also in the form of a diagram. There is, however, a very distinct difference between the kind of information that can best be recorded in diagrams and in tabular form. When there are only a comparatively few dimensions or sizes, varying by definite intervals, a table is better than a diagram; for example, if it is desired to list dimensions of machine details that are made in a specified number of sizes, a table giving the necessary dimensions has every advantage over a diagram. On the other hand, when there is a large number of combinations of different factors, the diagram performs a service that a table cannot, unless it is made so large and elaborate as to be impracticable. For example, a diagram relating to the horsepower transmitted by gears of different pitches, widths of face, numbers of teeth, and running at different speeds, is entirely practicable; whereas a table giving all such possible combinations would be too voluminous.

Whenever all the facts can be simply and easily recorded in a table, that method is generally best. If the variables are so many that a table becomes too voluminous, then the diagram will best fill the requirements.

Often diagrams are useful for visualizing a trend or tendency, because a curve will show this much more clearly than a set of figures. This, however, is a use for the diagram distinctly separate from that contemplated in the foregoing, where tables and diagrams are used merely as convenient methods for recording information, and for obtaining unknown dimensions and sizes that depend upon, or correspond to, some known dimension.

Diagrams, Valve. See Valve Diagrams.

Dial Feeding Mechanisms. Automatic feeding mechanisms of the dial type are used in conjunction with power presses for parts which have been partly finished by previous operations. The parts to be operated upon are placed in the pockets of the dial feeding mechanism, and as the punch descends the dial revolves automatically, stopping just before the punch enters a pocket After the operation is performed, the part is automatically ejected from the dial, leaving the pocket empty for another cup or blank. There are two different types of dial feeds in general use. The *friction-dial feed* consists of a plain disk which revolves continuously in combination with stationary guides and gages above it, so that the pieces placed on the disk are fed accurately under the punch. In order to insure reliable action, there is usually a finger or gripping movement which places and

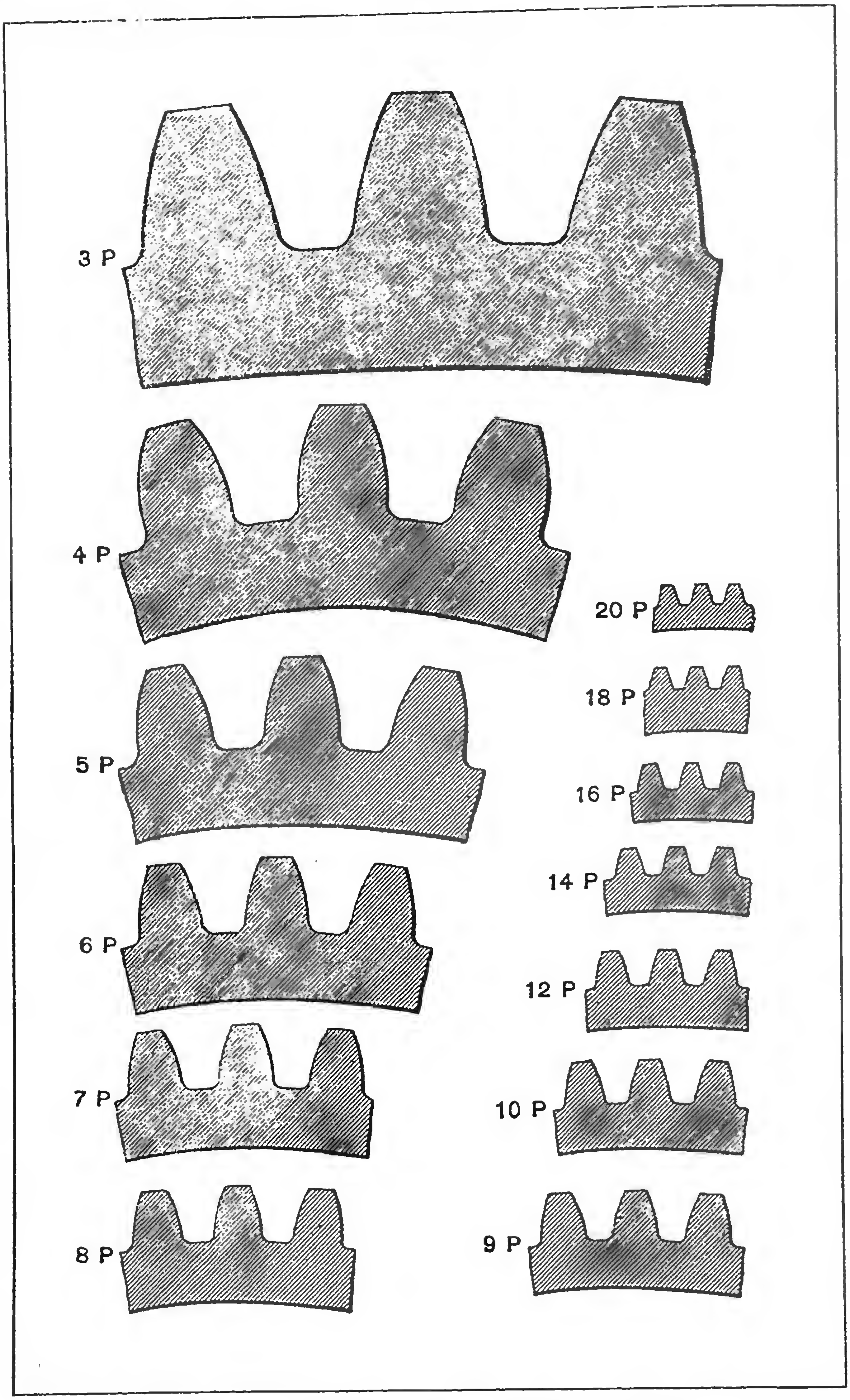
holds the work in the correct position. The friction-dial feed is preferable for redrawing short shells or pieces which are not liable to topple over. The other type is known as the *ratchet-dial feed* and consists of a circular plate which connects with the main shaft through a medium of cams and pawls so as to receive an intermittent rotary motion. This disk has a number of holes or pockets to receive either the work or dies. By means of this feed, it is possible, in many cases, to subject the pieces to two or three consecutive operations without rehandling. Feed mechanisms of the dial type are commonly used for carrying blanks, shells, or cup-shaped parts under the punch to receive a second and third operation. They are extensively employed in connection with the manufacture of brass goods, trimming, buttons, cartridge and primer shells, and tubes for pen and pencil cases, and many other specialties.

Dial Gage. The dial gage is a form of gage having a graduated dial and a hand which is connected to a test-point by a system of multiplying levers, so that a very slight movement of the test-point is greatly magnified by the indicating hand. This test-point is placed in contact with the part to be tested, and variations, either in size, alignment, or concentricity, depending upon how the gage is used, are shown by the movements of the hand relative to the dial, which is graduated to read to thousandths of an inch. Dial gages are used in combination with many different forms of gaging devices.

Dial Indicator. See Dial Gage.

Diamagnetism. Materials, like iron and steel, that are attracted by the poles of a magnet, are known as "magnetic"; those that are not attracted by a magnet are generally known as "non-magnetic." It has been shown, however, that practically all substances are acted upon in some maner by a sufficiently strong magnetic pole, but only a comparatively small number are attracted like iron, while the great majority of materials are repelled. Those substances that are repelled by the magnetic pole have been termed "diamagnetic." The strongest of all diamagnetic metals is bismuth; that is, of all substances this metal is repelled by a magnetic pole more than any other. Its diamagnetic qualities are so pronounced, in fact, that they can be detected by means of any good permanent magnet. Of the metals, gold, silver, copper, lead, zinc, antimony, mercury, and bismuth are all diamagnetic, while tin, aluminum, and platinum are attracted by a very strong magnetic pole.

Diametral Pitch. The common method of designating the size of the teeth of cut gearing is by giving the *diametral pitch*, which



Gear Teeth of Different Pitches Shown Full Size

is a number representing the number of gear teeth per inch of pitch diameter. For example, a gear of 6 diametral pitch has 6 teeth around its circumference for each inch of pitch diameter; therefore, if a gear of 6 pitch has 60 teeth, the pitch diameter must equal $60 \div 6 = 10$ inches. The *circular pitch*, which is sometimes used for designating the sizes of very large gear teeth and especially for cast gears, is equal to the dimension from the center of one tooth to the center of the next one measured along the pitch circle. If 3.1416 is divided by the circular pitch, the equivalent diametral pitch will be found, and inversely, if 3.1416 is divided by the diametral pitch, the result will equal the circular pitch.

The diametral pitch system is so arranged as to provide a series of tooth sizes, just as the pitches of screw threads are standardized. (See illustration.) Inasmuch as there must be a whole number of teeth in each gear, it is apparent that gears of a given pitch vary in diameter according to the number of teeth. Suppose, for example, that a series of gears are of 4 diametral pitch. Then the pitch diameter of a gear having, say, 20 teeth will be 5 inches; 21 teeth, 5¼ inches; 22 teeth, 5½ inches, and so on. It will be seen that the increase in diameter for each additional tooth is equal to ¼ inch for 4 diametral pitch. Similarly for 2 diametral pitch the variations for successive numbers of teeth would equal ½ inch, and for 10 diametral pitch the variations would equal 1/10 inch, etc.

The center-to-center distance between two gears is equal to one half the total number of teeth in the gears divided by the diametral pitch. While it may be desirable at times to have a center distance which cannot be obtained exactly by any combination of gearing of given diametral pitch, this is an unusual condition and ordinarily the designer of a machine can alter the center distance whatever slight amount may be required for gearing of the desired ratio and pitch. By using a standard system of pitches all calculations are simplified, and it is also possible to obtain the benefits of standardization in the manufacturing of gears and gear-cutters. The range of diametral pitches ordinarily used is 1, 1¼, 1½, 1¾, 2, 2¼, 2½, 2¾, 3, 3½, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, and 20. For very small gears, finer pitches of even number diametral pitches are employed. The diametral pitch system, which was long known as the "Manchester pitch," was originated by a Swiss named John George Bodmer, in his plant at Manchester, England.

Diametral Pitch in Plane of Rotation. Formulas for designing herringbone gears often contain what is termed "diametral pitch in plane of rotation." The diametral pitch in plane of rotation equals the number of gear teeth divided by the pitch diam-

eter, the same as in the case of a spur gear. The diametral pitch obtained in this way may either be some standard pitch or it may be an odd fractional pitch. Diametral pitches such as 2, 2½, 3, 3½, 4, 5, 6, etc., are examples of standard diametral pitches such as are found in tables of tooth parts.

Herringbone-gear teeth are cut to some standard tooth depth. The stub form of tooth is the most common, and the total depth of the American standard stub tooth equals 1.8 divided by some standard diametral pitch. If a full-depth tooth is required, then 2.157 is divided by some standard diametral pitch. If the diametral pitch in the plane of rotation is not standard, it cannot be used in formulas for addendum, dedendum and total depth, because the tooth depth would not be standard. Herringbone gear designing problems may be divided into three very general classes. In considering these three classes or cases, reference to diametral pitch will be made by way of illustration, but the same principle would apply if the gear were designed on the basis of circular pitch.

Case 1: When a special herringbone-gear hob or cutter is used having some standard diametral pitch in the plane of rotation: Such a hob or cutter is special in that the tooth thickness is reduced an amount depending upon the helix angle, thus making the circular pitch of the gear in the plane of rotation equivalent to a standard diametral pitch.

Case 2: When a standard spur-gear hob is used because a herringbone-gear hob is not available: In this case the diametral pitch of the hob represents the normal diametral pitch of the gear and the diametral pitch in the plane of rotation will be an odd fractional pitch unless the pitch in the plane of rotation is also made standard, as explained in the next paragraph.

Case 3: When a standard spur-gear hob or cutter is used and a special helix angle is selected to make the diametral pitch in the plane of rotation standard as when spur gears are to be replaced by herringbone gears without changing the center distances between the shafts or the ratio.

Diamond. A form of the chemical element carbon which is extremely hard. In its pure form, it is exceedingly clear and transparent, but numerous impure varieties, known as "black diamond" and "bort," are dark in color. These latter are used in the industries for dressing grinding wheels, and in some cases for cutting tools. The specific gravity of carbon in the form of diamond is about 3.5.

Diamond Chisel. A chisel with a narrow blade having the cutting edge at one corner of a square-shaped end. It is intended for cutting V-grooves having a sharp bottom.

Diamond Dust. Diamond dust is commonly used for lapping or grinding small precision work in tool-rooms, watch factories, etc., where great accuracy is required. The grades of diamond dust used for charging laps are designated by numbers, the fineness of the dust increasing as the numbers increase. The diamond, after being crushed to powder in a mortar, is thoroughly mixed with high-grade olive oil. This mixture is allowed to stand 5 minutes and then the oil is poured into another receptacle. The coarse sediment which is left is removed and labeled No. 0, according to one system. The oil poured from No. 0 is again stirred and allowed to stand 10 minutes, after which it is poured into another receptacle and the sediment remaining is labeled No. 1. This operation is repeated until practically all of the dust has been recovered from the oil, the time that the oil is allowed to stand being increased finally to several hours, in order to obtain the smaller particles that require a longer time for precipitation.

Diamond Lap. Very small holes in precision work are often finished after drilling, by using a rotary diamond-charged lap. Laps of this kind are made of mild steel, and the slightly enlarged working end is charged with diamond dust, thus converting it into an efficient grinding wheel for small holes. Such a lap may be charged by rolling it between hardened steel plates, after placing a little diamond dust and oil on the lower plate. The spindle is revolved by a round belt connecting with the grinding pulley on the countershaft. The spindle speeds for small grinding and lapping operations usually vary from 10,000 to 12,000 revolutions per minute.

Diamond or Precision Boring. The expression "diamond boring" or "precision boring" is applied particularly to the boring of holes on machines designed for high speeds and the use of carbide or diamond boring tools. Diamonds have long been used for machining materials that were too hard to yield to the cutting edges of steel tools, but their use for machining the softer materials requiring an extremely hard tool is a later development. After tungsten carbide became available, it was used in place of diamond tools for most precision boring operations. The cemented tungsten-carbide boring tools are used in the form of small cutting tips, brazed into tool-holders. The term "diamond boring" is often applied even when carbide tools are used. Light cuts and fine feeds are employed in precision boring and to obtain the best results, the cutting edge must be lapped to a high polish, so that there will be no grinding marks on the cutting edge.

Tungsten carbide, like the diamond, must be used where vibration is reduced to a minimum. If there is any considerable amount of vibration, the keen hard cutting edge of the tungsten

carbide will be destroyed. Tungsten carbide is capable of scratching a sapphire, which is next to the diamond in hardness. The hardness is approximately 90 on the Rockwell A hardness scale. while the diamond hardness is 100. Tungsten carbide, however, is more uniform and dependable than a diamond, and is not so likely to chip. Moreover, the cutting face and edge desired can be more readily obtained on tungsten carbide when sharpening.

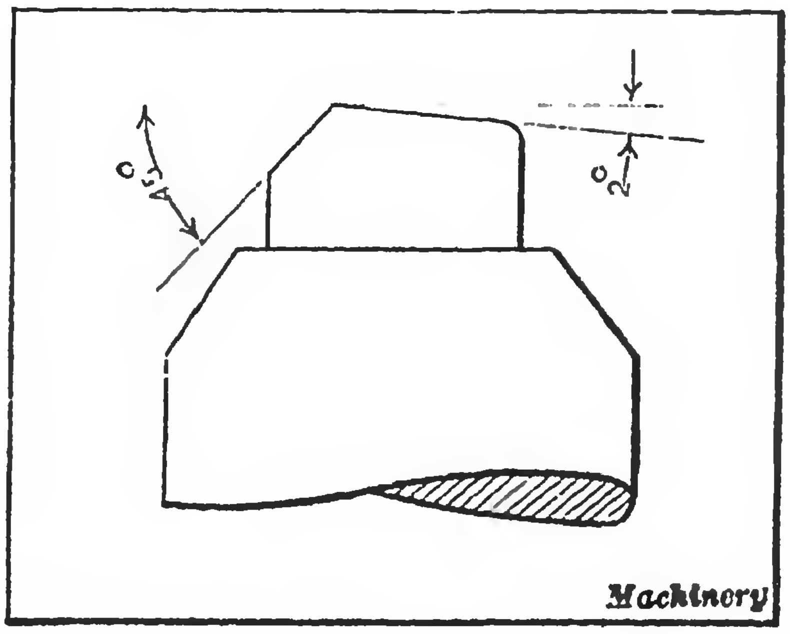
Diamonds for Wheel-Truing. There are five different kinds of diamonds employed for truing grinding wheels, namely, Jaegers-Fontin, Ballas, black carbon, brown bort, and gray bort. The Jaegers-Fontin diamond is very hard and is the most brittle kind. It is grayish in color, irregular in shape, and possesses a very coarse grain. It fractures easily, usually at the wearing point, which chips off in little pieces. It may be set firmly without difficulty on account of its rough surface, but this surface makes it difficult to true wheels satisfactorily. In addition to these disadvantages, these diamonds are very expensive.

The Ballas type of diamond is a clear white stone, hard and brittle, but not to the same degree as the Jaegers-Fontin type. It is of a finer grain than the latter and generally gives more satisfactory results. The black diamond is soft but tough. It does not break but wears too quickly to be suitable for the purpose of truing grinding wheels. It is also very expensive. Of the bort types, the brown stone has a smooth surface and a fine grain, and is transparent. It is not as hard, however, as either the Jaegers-Fontin or the Ballas types, but it is very tough. The color of the stone is produced by the presence of iron oxide. The gray stone is much the same as the brown stone except for the color and for the fact that it is a little harder and more brittle. The bort stones are sufficiently hard to withstand all reasonable wear, their shape is such as to permit them to be securely set and they are relatively inexpensive.

The shape of the wheel-truing diamond is an important factor in determining its value, the ideal shape being an eight-sided stone. The diameter and face of the grinding wheel, its hardness, and the type of abrasive used are factors which should be considered when determining the proper size of stone to use. A diamond should never be used on a grinding wheel which is mounted on a loose spindle, as the tendency will be to shatter the diamond and probably to pulverize it. The diamond should never be rammed into the grinding wheel, and should not be traversed across the face of the wheel too quickly. It is important that a stream of water be used during the truing-up operation.

The diamond holder should be inclined downward 10 to 15 degrees from a radial position. The purpose of this "drag angle" is to obtain new cutting facets on the diamond.

Diamond Tools for Metal Cutting. Tools with diamond cutting points have been used to a limited extent for certain metal-cutting operations on precision work, especially when a tool of extreme durability is required to obtain the necessary accuracy. Diamond tools, however, have been replaced largely by the cemented carbide tools. Diamond tools have been used chiefly for machining non-ferrous metals, such as brass, bronze, aluminum and German silver. Various non-metallic materials may be cut readily with diamond tools, as, for example, hard rubber, fiber, strawboard, gutta-percha, and bakelite. Diamond tools are especially adapted to fine instrument and tool work.



Shape of Diamond for Turning Operations

Kinds of Diamonds Used: Brown Brazilian or African diamonds which are off color and unsuitable for jewelry are used for metal cutting. Black or "carbon" diamonds used in dressing grinding wheels have been used, and while satisfactory results were obtained in cutting rubber, bakelite, etc., these diamonds were found unsuited for the precision cutting of metals. It is essential that the diamonds used for this purpose be of close grain and free from carbon spots, so that a keen cutting edge may be ground. The largest diamonds used for industrial purposes are about 20 carats, and the smallest size used in a cutting tool, 1/8 carat. It is advisable to use a diamond of the largest possible size that is suitable for the work at hand, as this permits the diamond to be reset if necessary; also a large diamond has a greater percentage of salvage value than a small diamond, thus making the net cost much less.

Shape of Diamond Tool: Diamonds can be ground for outside turning, boring, radius turning, facing, and, in fact, for almost any lathe operation for which high-speed steel tools are suited. Pointed tools are ground to various included angles between 60 and 120 degrees. Turning tools are usually ground to a 45-degree angle at the left-hand end of the cutting edge (see illustration), the width of the bevel depending upon the depth of cut to be taken with the tool. The wide front portion of the cutting edge is ground at an angle of 2 degrees from the bevel, and a clearance of 2 degrees is ground on the front face of the diamond when the tool is to be used for cutting brass and aluminum.

Diamond Wire-Drawing Dies. Dies made from diamonds are used extensively for drawing small sizes of wire. Such dies are now employed almost exclusively for wire ranging from 0.080 inch down to 0.0004 inch in diameter; and owing to their durability and other advantageous features, diamond dies are now finding quite a wide application for drawing larger sizes of wire. When they are properly made, the use of these dies is economical. Although their first cost is high, diamond dies retain their accuracy for a long time and they can be repeatedly recut, so that the item of die cost which must be charged against the expense of manufacturing wire, is distributed over a very large quantity of the product. For this reason, diamond dies have largely replaced the use of dies made from steel, iron, ruby, or sapphire. Most diamond dies are made of rough diamonds from the South African and Australian mines, the diamonds used for this purpose being of a grade which is unsuitable for use in jewelry.

These dies consist of a body made from brass or bronze through which is drilled a clearance hole for the wire, which hole is counterbored to a certain depth. The counterbored hole constitutes a seat for the diamond which is set in the center of the hole with molten brass or solder poured in around it until the hole is filled. The diamond is perforated by a tapering polished hole through which the wire is drawn. In many wire-drawing mills, the sizes for which diamond dies are used are limited to from 0.002 to 0.040 inch. The size of diamond for a wire 0.040 inch in diameter is about 3 or 3½ carats, while ½-carat stones will suffice for dies for drawing wire 0.010 inch in diameter.

Dibasic Acid. In chemistry, an acid which has two atoms of hydrogen in each molecule replaceable by a metal.

Die. The term "die" is often applied to an entire press tool including both upper and lower members, while the names "punch" and "die" are used to designate parts or sections of a complete die. These main sections ordinarily are classified with reference to shape, rather than by location, notwithstanding the fact that the punch is usually but not invariably the upper member. When the name "die" is applied to part of a press tool, it refers to the member that has an opening or cavity to receive a punch, for blanking, drawing, or otherwise forming whatever stock or part is confined between the punch and die members. See also Punch.

Die-Block. A block in which the die is held in a punch press. The die-block itself is bolted to the bed of the press. It is also known as Bolster.

Die-Casting. The term "die-casting" generally refers to a casting that has been made in a metallic mold or die, into which

molten metal has been forced under the influence of either mechanical or pneumatic pressure. Die-castings do not include so-called "hot-pressed" or "die-pressed" forgings, because in this process, the metal placed in the dies is not molten, but merely in a plastic or semi-plastic condition. The definition also excludes castings that are poured by gravity into metallic molds, the latter generally being known as "permanent-mold" castings. Die-castings may be defined as castings produced by forcing molten metal into metallic dies by a force greater than atmospheric pressure. This definition differentiates them from the class of castings made by the permanent mold process, sometimes referred to as die-castings. Die-castings are uniform, accurate, and cheap, equal to the product of a skilled workman, but produced by unskilled labor. Their advantage over machined parts is due to the rapidity with which they are produced and the relatively small amount of labor necessary after they are cast to produce a finished piece ready to be assembled.

The process of die-casting requires the use of a die-casting machine, and consists essentially in melting the die-casting alloy in a suitable container and forcing it, under pressure, into metallic molds or dies, allowing it to cool in them, and then opening the dies and removing the casting, thereby producing smooth finished castings requiring little or no machining and being ready for buffing or plating without any grinding or other abrasive process. The method is best adapted to small intricate parts where accuracy and uniformity are essential. The history of type founding shows that in 1838 the first casting machine for type, invented by Bruce, was a machine that involved the principles of die casting as it is now practiced. More recently, in 1885, Mergenthaler brought out the linotype machine. This machine is a good example of a die-casting machine. However, as understood to-day, *die casting* is a broader term than *type casting*, although its development is, without doubt, due, in part, to the success of the linotype machine. The properties of die-castings will depend upon the nature of the alloy used. The die-casting process is best adapted to alloys of comparatively low fusing points.

Die-Casting Alloys. Any metal intended for die-casting purposes must flow readily in the molten state, so that it can be forced under pressure to all sections of the die-cavities. In cooling, the metal must form smoothly, so as to prevent as far as possible the necessity of subsequent machining operations.

Alloys of aluminum, copper, lead, magnesium, tin, and zinc can be die-cast successfully. Those with the lowest melting point, such as lead, tin and zinc, are the easiest to cast, because there is less wear and tear on the dies. Good machine steel, not even heat-

treated, can be employed for dies used to cast parts from the low-temperature alloys, whereas heat-treated alloy-steel dies are necessary for casting parts from aluminum and copper alloys. Zinc, aluminum, and copper alloys are the most popular because of their properties.

The applications of zinc die-castings seem almost endless. They have proved satisfactory for many automobile and machine parts; for ornamental purposes; typewriter frames, telephone parts, gasoline pumps, clock cases, washing-machine gears, small motor end-housings, door handles, and thousands of other applications.

Zinc-base Alloys: Zinc-base alloys are easy to cast, are low in cost compared to other die-casting alloys, and have good physical properties at normal temperatures. They are highly fluid at casting temperatures and may be cast in thin sections at relatively low injection pressures. Because of the low injection pressures required, it is possible to use smaller machines for zinc castings than for aluminum castings of the same size. The low casting temperature of zinc alloys results in a minimum of die wear and permits the use of relatively inexpensive steels in the construction of the dies.

Tin-base Alloys: Tin lends itself well to die-casting because of its low melting point; but as its cost is high, the cheaper low-melting metals are generally selected, unless resistance to certain liquids is essential. Thus, tin-base alloys are used for die-casting syrup cups, soda-fountain appliances, milking-machine parts, and other articles that must be immune to the action of acids from foods and food products or to alkalies; the copper and lead content, however, must not be enough to form poisonous compounds with the liquids handled. Tin alloys have only a small shrinkage in cooling, and so they are particularly desirable when accuracy is essential in castings. Tin-base alloys are not adapted for highly stressed machine parts, but they do possess valuable bearing properties.

Lead-base Alloys: Lead-base alloys find wide application because of the resistance they offer to many chemicals. They are also extensively used for bearing purposes, toys, and novelties. They are naturally not adapted for stressed machine parts, because of their low strength. Neither are they suitable for parts that are to handle food products, because of the poisonous lead compounds likely to be formed.

The hardness of lead-base alloys can be increased by adding to the antimony content. Tin improves the strength and the fluidity.

Aluminum-base Alloys: Aluminum die-casting alloys possess the advantages of comparatively high tensile strength, light

weight, resistance to corrosion and ability to take a good polish and to hold it under normal atmospheric conditions. These advantages adapt them to a wide variety of applications. Light weight, good conductivity, and freedom from intergranular corrosion make these alloys particularly useful in the electrical industry. These alloys may be finished in a wide variety of attractive colors which have considerable surface endurance. Aluminum die-castings are used extensively for parts of vacuum cleaners, household appliances, cameras, motors, instrument housings and for a variety of other articles.

Copper-base Alloys: Copper-base alloys possess superior properties as regards strength, impact value, and elongation, and they are not affected by many chemicals or atmospheric conditions. The impact value of brass die-castings is greater than that of sand castings of the same alloy and equal to that of forgings in some cases. Copper alloys are in general the most difficult of all alloys to die-cast, require the largest sizes of die-casting machines, the highest injection pressures, and are, comparatively speaking, the most expensive.

Magnesium-base Alloys: Magnesium-base alloys are about two-thirds as heavy as aluminum and approximately one-fifth as heavy as brass. Magnesium-base alloys ASTM Nos. AZ91A and AZ91B are commonly used for die-casting purposes. Typical applications of these alloys are small tool handles and parts for airplanes, typewriters, and adding machines.

In addition to being light in weight, magnesium castings are easy to machine, have high dimensional stability and are non-magnetic and non-sparking.

Die Chasers. The inserted cutters used in threading dies are commonly known as *chasers.* These chasers are rigidly fixed in some dies; in others, they are adjustable radially within a limited range for cutting threads slightly under or over the normal diameter of the die. The chasers on automatic or self-opening dies may be withdrawn far enough to clear the thread and thus avoid backing off.

Die Clearance, Angular. The amount of angular clearance ordinarily given a blanking die varies from one to two degrees, although dies that are to be used for producing a comparatively small number of blanks are sometimes given a clearance angle of four or five degrees to facilitate making the die. See also Punch and Die Clearance.

Die Cushions. The term "die cushions" is applied to some pressure attachments for drawing dies, especially the pneumatic type. See Pressure Attachments for Drawing Dies.

Die-Holders. The die-holders used for solid or non-opening dies may be of the rigid type, the floating non-releasing type, or the releasing type. For turret lathe and automatic screw machine work, the non-releasing type, which is free to move in a lengthwise direction a limited amount, is used extensively, although the releasing design is preferable under certain conditions. With this latter type the die is released or is not held against rotation after the thread has been cut to the required length. When the forward motion of the turret slide discontinues, the rotation of the screw thread draws one section of the releasing die-holder farther forward until the driving connection between the two sections disengages; the die then continues to revolve with the work as long as the latter continues to run forward. When the spindle is reversed the die starts to rotate backward with it, but this reverse movement is stopped automatically by the die-holder, and the stationary die is then backed off the screw as the spindle continues its reverse rotation.

The releasing type of die-holder (which is intended only for non-opening dies) is used when it is necessary to govern closely the length of the thread, as, for example, when cutting a thread close to a shoulder. If the reversal of the machine is controlled by the operator, as in a hand screw machine, a releasing die-holder should be used, because, if the machine is not reversed at the instant a die of the non-opening type reaches the limit of its forward travel, the thread may be stripped or the die broken when attempting to cut close to a shoulder. When the releasing type of holder is applied to the threading spindle of a multiple-spindle automatic screw machine, if the threading operation is completed before the other operations, the releasing device permits the die to revolve loosely until all the operations are completed.

Dielectric Strength. The property of an insulating material which is a measure of the material's ability to withstand an electrical potential. The unit of measurement for thin-sheet insulators is volts per mil. Any stated value then is the maximum number of volts (electrical potential) per mil (thickness measured in thousandths of an inch) that an insulating material can withstand without rupture or puncture. As an example, a piece of slate of 0.010-inch thickness which breaks down under a voltage of 330 would have a dielectric strength of 33 volts per mil.

Die-Pressed Castings. See Brass Forging and Hot-pressed Brass Parts; also Cold-pressed Castings.

Die-Pressed Steel Parts. See Hot-pressed Steel Parts; also Cold-pressed Forgings.

Dies. See type of die: Bending Dies; Blanking Dies; Burnishing Dies; Compound Dies; Continental Dies; Curling and Wiring Dies; Drawing Dies; Embossing Dies; Follow Dies; Forming Dies; Gang or Multiple Dies; Steel Rule Dies.

Dies, Chromium Plated. See Chromium Plating.

Dies, Drop-Forging. See Drop-forging Die Materials.

Diesel Engines. The Diesel engine is an internal combustion engine which uses oil as a fuel, and which differs from other types of oil engines principally in that the fuel is introduced directly into the cylinder of the engine without previous gasifying or vaporizing, it being merely introduced in the form of a spray by an atomizer, and in that the engine requires no special ignition device. In the four-stroke cycle Diesel engine, therefore, air alone is drawn into the cylinder on the charging stroke, this air being compressed on the return stroke to a very high pressure—about 500 pounds per square inch—the result of the compression being that the air is heated to a high temperature and that the heavy oil injected into the air at the end of the stroke will be immediately ignited by it. The oil burns rapidly, but without explosion, the pressure exerted by the expansion due to the combustion of the oil producing the power impulse on the piston. Hence, the Diesel engine embodies two distinct features in which it differs from other internal combustion engines: the compression pressure is much higher than that in any other oil or gas engine, and igniting devices are not required, as the temperature of the compressed air is high enough to cause ignition of the oil.

Diesel engines may be broadly divided into two main types or classes: (1) The four-stroke cycle and (2) the two-stroke cycle engine. In both types of engines, the cylinder is filled with air at atmospheric pressure, the air being compressed by the piston until the pressure becomes about 500 pounds per square inch, and the compression raising the temperature to about 1000 degrees F. or more. At this instant a small quantity of oil fuel is forced into the very hot high-pressure air by means of a blast of air at still higher pressure. The oil is broken into a fine spray and its admission lasts only for about one-tenth of the downward stroke. During this short time the oil is burned in the hot air, producing a fairly constant pressure equal to the compression pressure at the end of the compression stroke.

The Diesel engine was invented by Rudolf Diesel, a German engineer, who secured the first patents in Germany on this engine in 1893, and who brought out the first successful engine in 1897 at the Augsburg Works, in Germany.

Die-Sets. A die-set consists of a punch holder, base, and pillars or guides for accurately holding the upper and lower members in alignment and as a complete unit which may readily be applied to a press. Die-sets of this general type are manufactured in different sizes. They are so arranged that the user merely equips the die-set with whatever punches and dies or die openings, are required for a given operation.

Die-Sinking. Die-sinking is the process of forming an impression in a die (usually for drop forging). It is done by means of a die-sinking type of milling machine in conjunction with hand chipping, filing, scraping, and "typing" if necessary.

A *die-sinking machine* is a type of vertical-spindle milling machine especially designed for the use of diemakers in milling out the impressions in drop-forging dies, etc., or for finishing recesses of circular or irregular shape. The simple type of die-sinking machine is largely manipulated by hand. In the operation of the Keller die-sinking machine, the cutter is guided over the work and in and out by means of a tracer point which follows the outline and contour of a model or master placed directly above the work. This master may be made either of plaster, cement, or wood. Only a slight pressure is exerted against the master by the tracer, while at the same time sufficient pressure is applied to the cutting tool. Rectilinear motions in three directions are provided, these motions being obtained by means of lead-screws which operate the different slides. Automatic feeds are provided both vertically and horizontally and there is a quick return in both directions for the horizontal movement. There is also a contouring or profiling movement by means of which a templet, or the ridges or grooves of a master, may be followed. When the work leaves the machine, it requires only a minimum amount of hand work for finishing.

Universal Die-sinker: A die-sinking machine known as a universal type, is so designed that both cherrying and straight die-sinking operations can be performed without any changes of set-up or any special attachments. The principal feature of the machine is an oscillating head by means of which an ordinary die-sinking cutter can be moved through a circular path, so that both roughing and finishing cherrying operations can be performed. A double binder provides for locking the entire oscillating head solidly to the column when the machine is to be used for ordinary die-sinking cuts in which the table elevating and transverse movements are employed. The machine is of the vertical type and has a knee supported by an elevating screw and sliding on vertical ways on the column. This knee carries a table which travels in both directions. The oscillating head is moved entirely by hand, through a handwheel on the front of the head.

This machine will perform many types of cherrying cuts that are impossible on previous styles of the machine. For instance, by combining the rotary table feed and the oscillating cutter movement, it is possible to sink a spherical cut in the surface of a die and finish it ready for the polishing operation, all with the same cutter and without the use of an attachment.

Die-Sinking, Hub Method., See Hub Method of Die-sinking.

Die Slotters. The openings in blanking dies are often machined in slotters especially designed for work of this class. A die slotter which represents a typical design is equipped with a short-stroke ram which can be set at an angle with the work table for machining the required amount of clearance. The table is circular and can be rotated for slotting circular openings. This circular table is mounted on compound slides which provide lateral and transverse feeding movements. The machine is of the column-and-knee construction, thus providing vertical adjustment for the work table. Blanking dies are also slotted on an ordinary column-and-knee type milling machine, by using a slotting attachment.

Dies, Sectional Type. Certain advantages are claimed for the sectional stamping die over the solid die. In making repairs on dies of this type, it is only necessary to remove the damaged section and replace it with a new part. Other things being equal, this is a decided advantage. Furthermore, difficulties encountered in hardening a large solid die-block are not met with in the case of the sectional die; and each section can be accurately ground and fitted after hardening, thereby correcting errors due to distortion in hardening. In this way, each section can be made identical with every other. The accuracy that can be obtained in making sectional dies is also of importance.

Sectional dies are used extensively in the production of armature laminations for electric motors and generators, and are also applicable to the manufacture of other classes of stampings containing a large number of perforations. The only essential difference in design between the sectional lamination die and the solid die is that the punch holes in the sectional die are formed by sections arranged radially and accurately fitted and assembled on a plate.

Die Steel, Cold-Drawing. See that class of tungsten steel called Wortle Steel.

Dies, Thread-Cutting. Most external screw threads are cut by means of dies, because tools of this class not only cut threads rapidly but, when properly made, are capable of producing screws that meet most commercial requirements as to accuracy. Dies may be divided into two general classes, namely, those that are

removed from the screw thread by being backed off or unscrewed and those that may be opened so that the cutting edges clear the screw thread, thus permitting the die to be removed by traversing it over the work in a lengthwise direction.

The *non-opening dies* are capable in some cases of hand adjustment, but the object of this adjustment is to vary the size of the die. There are four types of non-opening dies in common use, which may be designated as (1) solid dies, or those that are rigid and incapable of any adjustment for varying the diameter; (2) flexible dies, or those that are split in one or more places and may be adjusted to some extent by compressing or expanding; (3) sectional dies, or those formed of two adjustable sections; (4) rigid adjustable dies of the chaser type, having inserted chasers that may be adjusted radially within certain limits either for maintaining a standard size or for varying the size slightly.

Self-opening Dies: The different designs of *automatic* or *self-opening* dies differ principally in regard to the mechanism for opening the die-chasers at the completion of a cut, the method of closing the chasers to the cutting position after removing the die, and the method of supporting the chasers against radial thrusts. Self-opening dies, in general, are formed of two main sections. One section, which includes the shank and inner part of the die body, is attached to the turret, spindle, or other part of the machine. These two main sections have a certain relative motion for opening the die or releasing the chasers from the work and for closing the chasers to the working position. This motion for operating the die may either be parallel to the axis of the die, rotary, or helical.

Die Taps. Die taps, also known as "long taper die taps," are used for cutting the thread in a die in one single operation from the blank and are supposed to be followed by a hob tap. The die tap is provided with a long chamfered portion and a short straight or parallel thread. If it is to be followed by a hob tap, the parallel portion should be slightly under the standard size so as to leave enough metal for the hob tap to remove to insure the correct size of the die. This difference in size should not only be on the top of the thread but in the angle of the thread as well, so that any inaccuracy in the lead of the thread may be taken care of. The difference must be very slight, as the hob cannot remove very much stock, as it has a very short chamfer and very small chip room for the stock removed. If this is not taken into consideration, the dies may be injured in the sizing operation. Die taps are very similar to machine nut taps and are made almost exactly in the same way.

Dietzel Process. The Dietzel process is an electrolytic refining process for separating silver and copper, the process consisting in dissolving both of the metals (as anode) in a weak acid solution of copper nitrate. This solution is then transferred to another vessel and the silver is precipitated by metallic copper, after which the copper is deposited electrolytically.

Differential Accumulator. A hydraulic accumulator consisting of two cylinders of different diameters. The smaller cylinder is contained in the ram or plunger that fits into the larger cylinder. By the use of this machine very high pressures can be obtained.

Differential Back-Gears. See Back-gears of Differential Type.

Differential Block or Hoist. See Hoist.

Differential Gearing. This term is sometimes applied to planetary gear mechanisms, because of the differential motion or difference in the original motions which results in the final motion desired.

One of the important applications of differential gearing, at the present time, is found on automobiles. The object of transmitting motion from the engine to the rear axle through differential gearing is to give an equal tractive force to each of the two wheels and, at the same time, permit either of them to run ahead or lag behind the other as may be required in rounding curves or riding over obstructions. The axle is not formed of one solid piece, but motion is transmitted to the right- and left-hand wheels by means of separate sections, the inner ends of which are attached to different members of the differential mechanism.

Differential Indexing. See Indexing.

Differential Mechanism on Gear-Hobbing Machines. In cutting helical gears on hobbing machines without a differential, the required ratio which combines index and feed gears must be calculated with considerable accuracy as otherwise a serious error will result which will impair the accuracy of the gears. It frequently happens that the required ratio consists of prime numbers, especially when cutting right- and left-hand gears with one hob. To produce correct helical gears with their axes located parallel to each other, the errors for the right- and left-hand spirals must be the same, otherwise there will not be a bearing on the whole length of the teeth. If the hobbing machine has a differential, it is not necessary to have a right- and left-hand hob for cutting any angle up to 30 degrees; on the contrary, better results are obtained by using only one hob for both right-

and left-hand spirals because if there is any distortion in hardening, the right-hand hob will be different from the left-hand.

If the machine has a differential mechanism there is no variation in the helical movement when the number of teeth is increased or decreased or the feed is changed. On machines not provided with a differential mechanism, gears of the same pitch but with different numbers of teeth, must be calculated for separately, and the slightest change in the feed will require a separate calculation. A change in the formula must also be made, if right- and left-hand gears with the same number of teeth are cut with one hob. The differential is also of importance when cutting worm-gears with a taper hob. The belief of many mechanics that the ratios and errors obtained by formulas are alike for all hobbing machines, with or without differential mechanism, is entirely erroneous. There is a great difference between the two ratios. In the one case the ratio represents the value of the indexing and the helical movement, and the slightest change of the "driver," *viz.*, numerator, will cause a great error if the "driven," *viz.*, denominator, is not also changed in the same proportion. In the other case, *i.e.*, with the differential, the ratio obtained refers to the angle or helical movement only, and adds or subtracts itself automatically to or from the ratio of the indexing gears.

Differential or Floating Levers. Differential levers are utilized in some mechanisms to control, by the application of a small amount of power, a much greater force, such as would be required for moving or shifting heavy parts. These levers are commonly applied to mechanisms controlling the action of parts that require adjustment or changes of position at intervals varying according to the function of the apparatus subject to control. The initial movement or force may be derived from a hand-operated lever or wheel, and the purpose of the differential or floating lever is to so control the source of power that whatever part is to be shifted or adjusted will follow the hand-controlled movements practically the same as though there were a direct mechanical connection. A floating lever is so termed because it is not attached to fixed pivots and does not have a stationary fulcrum, but is free to move bodily, or to "float" within certain limits and in accordance with the relative forces acting upon the different connections.

Dilatometer. A dilatometer is an apparatus for indicating and recording the volumetric changes in steel while it is subjected to heat, in order to determine correct hardening temperatures. The physical properties of steel, such as hardness, tensile strength, elastic limit, and elongation, are affected by internal physical changes. When heat is applied to a piece of steel it ex-

pands due to changing of the internal physical constituents. By measuring the steel while being heated, the dimensional changes serve as a guide to what is taking place within the steel.

The most important critical transformation is that which occurs just before a piece of steel is ready for quenching to obtain full hardness. This is called decalescence, and its presence has been noted by loss of magnetism and by a cessation in the heating rate. Decalescence may be noted by measuring the volumetric changes. The mechanical means of measurement is known as the dilatometric method. This method is said to be very accurate because it measures the changes throughout the mass of the metal.

Dimensioning Drawings. According to drafting-room practice as approved by American Standards Association, dimensions of parts that can be measured or that can be produced with sufficient accuracy by using an ordinary scale should be written in units and common fractions. Parts requiring greater accuracy should be dimensioned in decimal fractions. Dimensions up to and including 72 inches should preferably be expressed in inches, and those greater than this length, in feet and inches.

Where dimensions call for accurate machining with small tolerances it is recommended that the total dimension be given in inches and decimal fractions. In structural drawing all dimensions of 12 inches and over should be expressed in feet and inches. In automotive, locomotive, sheet metal and some other practices all dimensions are specified in inches.

The symbol (″) is used to indicate inches and common and decimal fractions of an inch. When all dimensions are given in inches the symbol is preferably omitted. A note may be placed on the drawing stating that all dimensions are given in inches. The symbol (′) is used to indicate feet and fractions of a foot. Dimensions in feet and inches should be hyphenated, thus 4′-3″; 4′-0½″; 4′-0″.

Fractions should be written with the division in line with the dimension line.

Dimension Lines and Extension Lines: Dimension lines should be fine full lines (broken where dimension is inserted) so as to contrast with the heavier outline of the drawing, and should be placed outside the figure or drawing outline wherever possible.

Extension lines indicate the distance measured when the dimension is placed outside the figure. They are made as light full lines starting 1/32 to 1/16 inch away from the outline and extending about ⅛ inch beyond the dimension line.

A center line should never be used as a dimension line. A line of the piece or part illustrated or an extension of such a line should never be used as a dimension line.

Dimension Figures: A dimension line must not pass through a dimension figure. If unbroken lines are used, as is common practice in structural drawing, the dimensions are placed above the line. When fractional dimensions of less than one inch are given, the numerator should be placed above the dimension line and the denominator below.

All dimension lines and their corresponding numbers should be placed so that they may be read from the bottom or right-hand edges of the drawing. All dimensions should be placed so as to read in the direction of the dimension lines.

When there are several parallel dimension lines the figures should be staggered to avoid confusion. Dimensions should be given from a base line, a center line or a finished surface that can be established readily. Over-all dimensions should be placed outside the intermediate dimensions. In dimensioning with tolerances, if an over-all dimension is used one intermediate distance should not be dimensioned.

In dimensioning angles an arc should be drawn and the dimension placed so as to read from the horizontal position. An exception is sometimes made in the dimensioning of large areas when the dimensions are placed along the arc.

Dimensioning Circles: A dimension indicating the diameter of a circle should be followed by the abbreviation "D" except when it is obvious from the drawing that the dimension is a diameter. The dimension of a radius should always be followed by the abbreviation "R." The center should be indicated by a cross or circle and the dimension line have one arrow-head.

Dimensioning Holes: Holes which are to be drilled, reamed, punched, swaged, cored, etc., should have diameter, given preferably on a leader, followed by the word indicating the operation, and the number of holes to be so made. Holes which are to be machined after coring or casting should have finished marks and finished dimensions specified.

If needed by the shop on account of the method of laying out, as in the button method, the chordal distances between holes on a bolt circle or the center-to-center distances between holes located by coordinates, should be calculated and dimensioned in decimals.

Dimensioning with Tolerances: Accurate dimensions which are to be established with limit gage or micrometer should be expressed in decimals to at least three places and the drawing should give the maximum and minimum limits between which the actual measurements must come. For *external* dimensions the maximum limit is placed above the line and for *internal* dimensions the minimum limit is placed above the line. This method should be used for smaller parts and where gages are extensively employed.

A second method, used for larger parts and where few gages are employed, is to give the calculated size to the required number of decimal places, followed by the tolerances plus and minus, with the plus above the minus, as 8.625D $\begin{smallmatrix}+.000\\-.002\end{smallmatrix}$

Changes in Dimensions: On a drawing, if a dimension must be changed, the changed figures should be underlined or otherwise marked. It is customary to note changes in dimensions in a tabulation on the drawing and to refer to them by letters or symbols placed after the altered dimensions.

Dimensioning Tapers: At least three methods of dimensioning tapers are in general use.

Standard Tapers: Give one diameter or width, the length, and insert note on drawing designating the taper by number.

Special Tapers: In dimensioning a taper when the slope is specified, the length and only one diameter should be given or the diameters at both ends of the taper should be given and length omitted.

Precision Work: In certain cases where very precise measurements are necessary the taper surface, either external or internal, is specified by giving a diameter at a certain distance from a surface and the slope of the taper.

Dinking Die. A dinking die is used for cutting out formed shapes from leather, cloth, or paper. It is, practically speaking, a hollow punch or cutter having a sharp cutting edge shaped to correspond with the contour of the part to be cut. Dinking dies may be used either in a press or may be driven through the material to be cut by a mallet. The body of a dinking die is usually made of high-grade iron and the cutting edge, which should be of high-grade tool steel, is welded to the body. The outside bevel which forms the sharp cutting edge should have an angle of about 20 degrees. A good block for the cutting edge of the die to strike against can be made of seasoned rock maple. This block is laminated or built up of small strips which are glued or bolted together with the grain endwise. A block of this kind will give better results if kept damp by covering it with a wet cloth when not in use.

Diode. There are two types of diodes. One makes use of a semiconductor material and converts an alternating current into a pulsating direct current. (See Semiconductors.) The other is a two-element (cathode and anode) vacuum tube which is used for rectification in power-supply circuits and modulation in electronic applications. In this, the cathode emits electrons which pass in a one-way stream to the anode.

Dip Brazing. A method of brazing metal parts by immersing them in liquid spelter solder. The spelter is contained either in a cast-iron tank or in a graphite crucible. See Brazing.

Direct Current. A direct current is a unidirectional current; as ordinarily used, the term designates a practically non-pulsating current. A pulsating current is a periodic current the values of which are always positive (or always negative) and thus as ordinarily employed, the term refers to a unidirectional current. A continuous current is a practically non-pulsating direct current.

Direct-Current Compensator. Same as Balancer.

Discard. The term discard as used in steel mill practice and in specifications relates to that portion of an ingot which is rejected to secure in the finished product freedom from piping or other injurious unsoundness and from undue segregation of chemical components. Discard always refers to the top portion of the ingot unless otherwise specified. Occasional specifications for special products require that a certain amount of discard be made from the bottom as well as from the top portion of ingots.

Discharge Coefficient. In fans, the ratio between the actual quantity of air discharged and the theoretical quantity is the discharge coefficient. It may be taken at about 0.8 for the short outlet from a fan casing.

Discharge Rate. In storage batteries, the discharge rate is the number of amperes that a battery will supply continuously for a given time, usually eight hours, three hours, or one hour. See also Storage Batteries.

Discharging Capacity of Pipe. See Pipe Discharging Capacity.

Disconnecting Switches. The term "disconnecting switch" is applied to that class of lever switches which are used for the purpose of isolating oil switches, transformers, and like apparatus, or for sectionalizing bus-bars or transmission lines. Such switches may be of any voltage rating, but generally the name "disconnecting" is associated with switches of a voltage rating over that where it is safe to operate the switch by means of the ordinary handle; that is, voltages over 650. Disconnecting switches may be divided into two general classes; namely, indoor and outdoor. *Indoor disconnecting switches* for voltages of 1200 or less are mounted on slate bases. For voltages over 1200 and up to and including 3500, these switches are mounted on marble bases, and for all voltages over 3500, they are mounted on wet-process porcelain insulators which are, in turn, mounted on a sheet-steel or other metal base. *Outdoor disconnecting switches*

are always mounted on porcelain insulators and of a type such as is used for supporting the line, these insulators being, in turn, mounted on channel-iron bases or some part of the transmission tower, or, in the case of the lower voltages, even on the ordinary wooden cross-arms.

Dished Die. A drop-forging die or any die used in the drop-hammer, is said to be "dished" when the force of the blows it receives causes the central part of the face to sink beneath the level of the remainder of the face. Dishing is usually traceable to a low grade of steel or to improper hardening.

Dish-Pan Idler. This is a type of supporting idler pulley used in connection with belt conveyors for giving the required trough shape to the belt in order that it may retain the material carried by it. The dish-pan idler consists of three pulleys, one smaller in the center, and two larger, having convex spherical surfaces on the inside, mounted at the ends.

Disk Clutch. A common design of disk clutch consists of a set of driving disks and a set of driven disks located alternately, so that each driving disk is between two driven disks. The driving disks may have key slots on their outer circumferences which are engaged by a key on the inner side of a driving drum, and the driven disks may be provided with lugs or key slots on the inner circumference for connection with the driven member.

Both the driving and driven disks of many clutches are metallic and run in oil. Steel disks about 1/16 inch thick are often used. One set of disks may be of bronze, or possibly of sheet copper. One multiple-disk clutch which has been extensively used has alternate disks of steel and phosphor-bronze. These disks have V-shaped grooves instead of being flat, frictional contact being between the angular surfaces. In dry-plate clutches, one set of plates may be faced on both sides with asbestos fabric, or cork inserts may be used. See Clutches.

Disk Grinders. Disk grinding is employed principally for truing plane surfaces by holding the work in contact with a revolving abrasive disk. On the *single-spindle disk grinder*, which is the most common type, the work is simply held against the disk by hand or by placing a surface opposite to the one to be finished against an angle-plate on the table of the machine. The table may be at right angles or some other angle to the face of the wheel and fed toward it by manipulating a lever. Special fixtures are also employed for carrying the work to the disk.

The *vertical-spindle disk grinder* has a large disk wheel which revolves in a horizontal plane. In operating this machine, the

parts to be ground are simply laid upon the revolving disk and are prevented from rotating with the disk by a cross bar. If the weight of the work is equal to three or four pounds pressure to the square inch of area to be finished, no additional pressure is required, but, in case it is much less than that, the output can be greatly increased by putting an additional weight on top of the work.

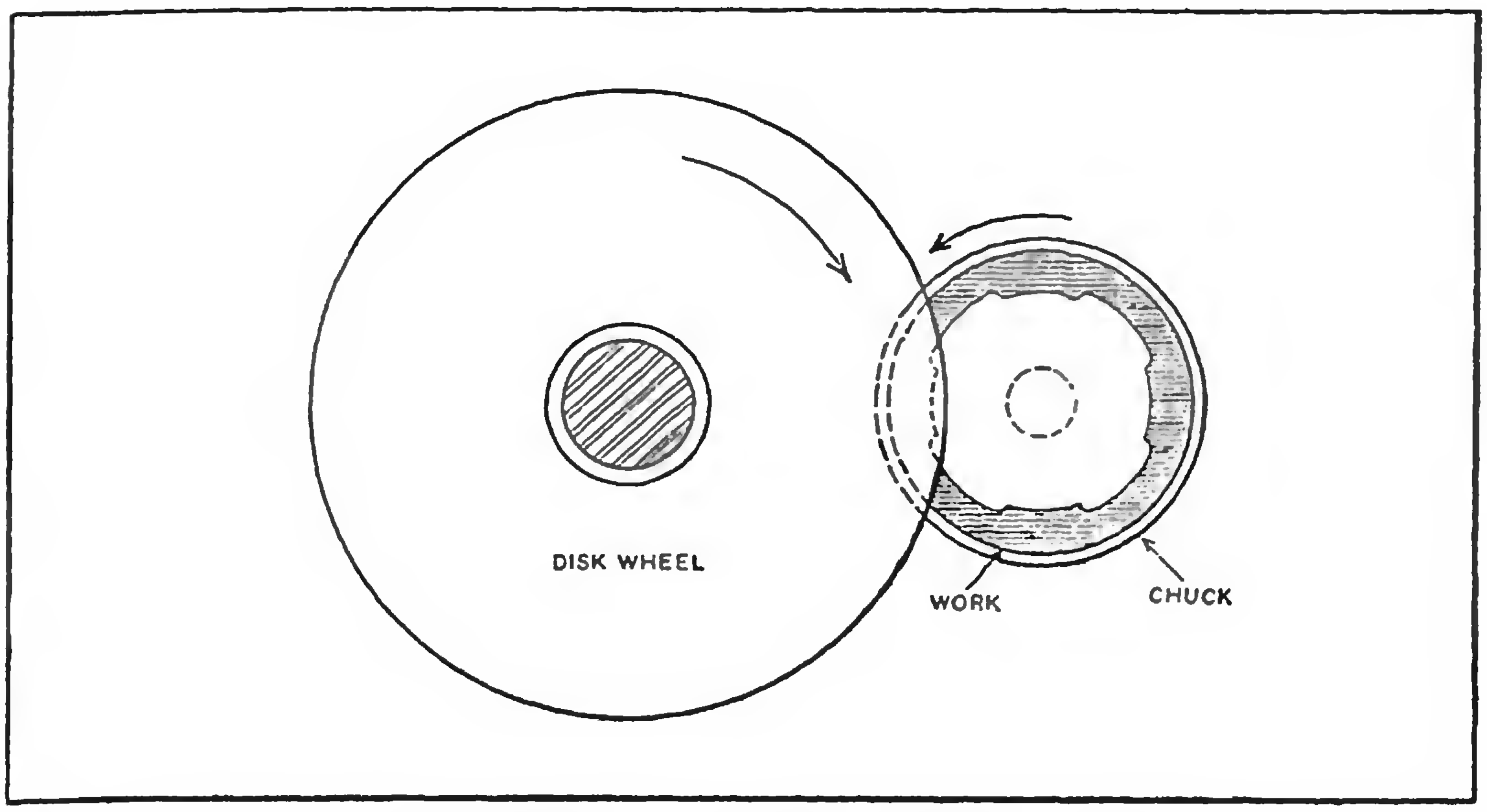
Such operations as grinding parallel sides of piston-rings, wrenches, cap-screw heads, and hexagon nuts are best performed on a *double-spindle disk grinder.* The two spindles are mounted in line, and carry an abrasive disk on the adjacent ends. The piece or pieces to be ground are placed in a work-holding device, advanced between the grinding disks, and ground in some machines by bringing the two disk heads together simultaneously, and in others by advancing only one head, the other one being in a fixed position. The table or work-holding device on both the single- and double-spindle machines is so constructed that an oscillating movement may be given to the work across the face of the grinding disk.

The *automatic double disk grinder* is for finishing parts having two opposite parallel sides of approximately equal area, such as piston-rings, electric iron plates, ball and roller bearing races, and gear blanks. In this machine the work is fed either from a magazine or by the operator into openings in a large continuously rotating wheel which carries the work past the disks.

Disk Grinding Allowances. The amount of stock to be removed, the area of the ground surface, and its distribution are important factors in disk grinding. The removal of from 0.005 to 0.050 inch of stock will usually "clean up" a surface. The following figures, taken from actual practice, represent allowances used in connection with one make of disk grinders: Drop-forged wrenches, from 0.008 to 0.015 inch; brass hexagon nuts, up to 2 inches in diameter, 0.015 inch; larger sizes, up to 0.030 inch; steel punchings, from 0.005 to 0.015 inch; cast-iron machine parts, from 1/32 to 1/16 inch; cast-brass machine parts, from 1/64 to 3/32 inch. The amount of stock that can economically be removed by disk grinding depends largely upon the nature of the material being ground. Cast metal is more easily ground than rolled or wrought material, and small thin castings are usually harder to grind than larger and thicker castings, owing to the greater density of the metal. When castings have a hard scale, it is often desirable to partially remove it before disk grinding. The hard scale is "broken up" either by grinding on vitrified

wheels or by tumbling, sand-blasting, or pickling. The latter method is the best for forgings or hot-rolled material that has considerable scale.

Disk Grinding by Rotary Method. The area that is in contact with the grinding disk is reduced, on some classes of work,

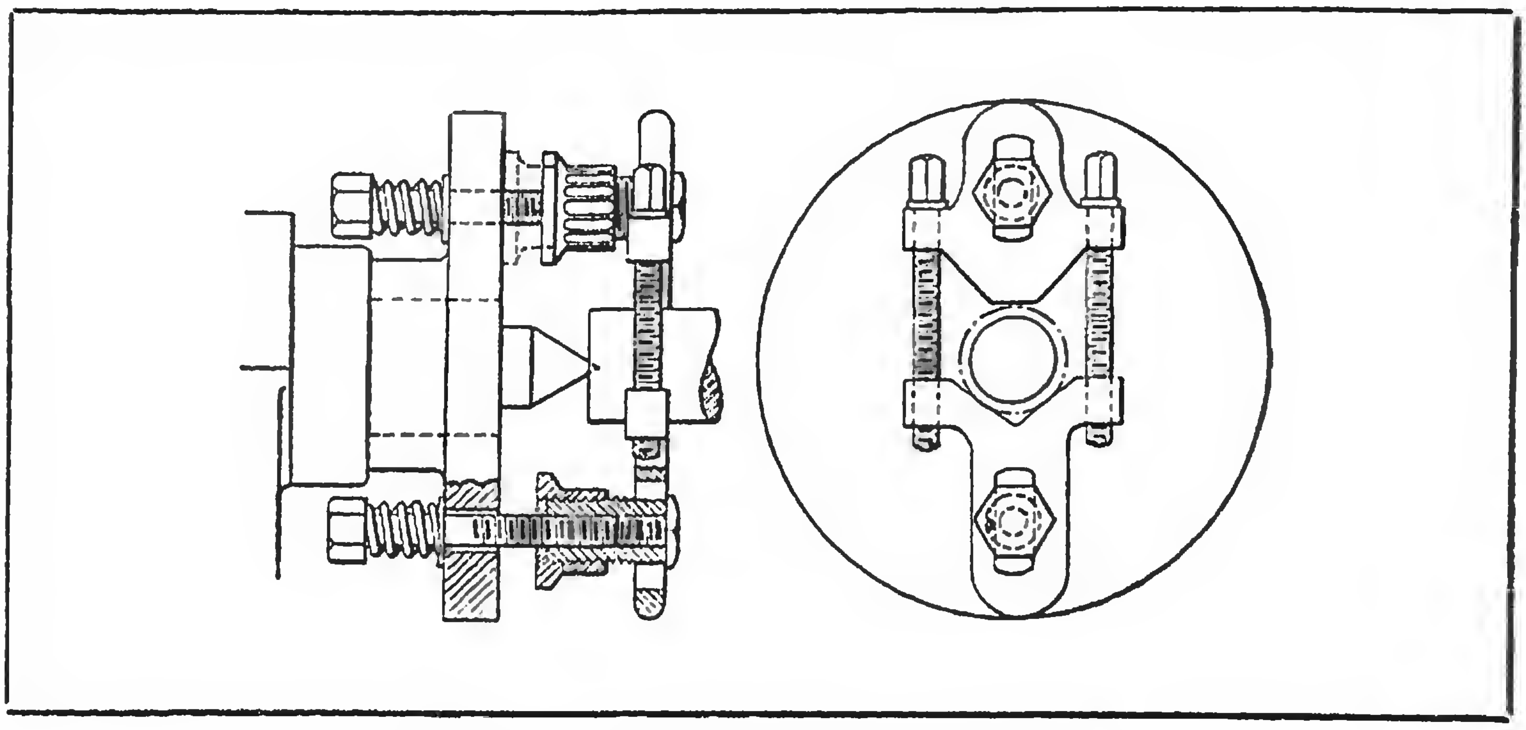


Rotary Process of Disk Grinding

by what is known as the rotary process. The diagram illustrates the principle. The part to be ground is held by means of a magnetic chuck, a faceplate, or a special fixture that is mounted in bearings and is free to rotate. The work table of the disk grinder is located so that the abrasive disk only makes contact with one side of the surface to be ground, as the illustration shows. The action of the grinding wheel rotates the work, so that the entire surface is ground as the result of the rotary motion. The rotary method is employed when the surfaces to be ground are large and unbroken and considerable stock must be removed; when the work is thin and easily heated in grinding, or fragile and easily sprung; and also when an accurate plane surface is required.

Disk Locating Method. Comparatively small precision work is sometimes located by the disk method, which is the same in principle as the button method, the chief difference being that disks are used instead of buttons. These disks are made to such diameters that, when their peripheries are in contact, each disk center will coincide with the position of the hole to be bored; the centers are then used for locating the work. See also Button Locating Method.

Dividing Engine. A linear dividing engine, which is believed to have been the first automatic machine used in the United States for graduating rules, was invented by J. R. Brown in 1850. This machine was not only fully automatic, but equipped with devices for correcting inaccuracies in the machine itself, such as might develop on account of wear.



Holdback Type of Faceplate Dog

Dividing Head. This is an attachment which forms part of the equipment of all milling machines of the universal type and of many machines of the plain type. It is also known as an indexing head and has index centers since the work usually is held between the centers of the head and a footstock. See Indexing Attachments.

Dogs or Drivers. When a part is held between the centers of a lathe for turning, it is rotated by a dog or driver which is secured to one end of the work and engages a slot in the lathe faceplate. These drivers are also used for operations other than turning, in order to transmit motion from a rotating member to the work; for instance, when a piece is held between the centers of the dividing head of a milling machine, a dog is used to connect the work with the dividing-head spindle, thus rotating the part either when indexing or for generating a helical groove. Dogs or drivers are also used on cylindrical grinding machines for rotating parts held between the centers, and for many other purposes. To minimize the danger incident to the use of the ordinary lathe dog with its unguarded set-screw which tends to catch in the clothing, especially when filing, many safety dogs have been designed. See Equalizing Dog; also Compensating Dog.

Hold-back Dog: The form of dog here illustrated is intended for driving a part when the outer end cannot be supported by the tailstock center of the lathe, as, for example, when boring a hole in the end of a cylindrical piece one end of which is supported on the headstock center and the other end in a steadyrest. This dog has two bolts which pass through the faceplate. These bolts are supported by spiral springs at the rear of the faceplate, which give the required flexibility and permit the bolts to be so adjusted as to draw equally on both ends of the dog.

Dolly Bar. A "hold on" or part which is used to back up a rivet during a riveting operation. It provides the necessary resistance to the peening of blows of the riveting hammer.

Dolomite. Dolomite is a natural refractory material composed of the carbonates of calcium and magnesium. It has the following chemical analysis: Calcium oxide, 30.4 per cent; magnesium oxide, 21.9 per cent; and carbon dioxide, 47.7 per cent. The value of its specific gravity ranges from 2.81 to 2.95 and its hardness ranges from 3.5 to 4.0 (Moh's scale). Dolomite is used as a flux in blast furnaces and in the basic Bessemer process. Like other fluxes, it must form with the gangue an ash and slag that will melt at about the same temperature as the iron, which will become fluid enough to be drawn off, and rich enough in lime for the desulphurizing reaction.

Double-Action Die. A drawing die which is used for drawing parts from flat stock into cylindrical and various other shapes. It is so named because the blanking and drawing punches have independent movements which are derived from the two slides of a double-action press; hence, the name of the die, in this case, indicates the type of press in which it is used.

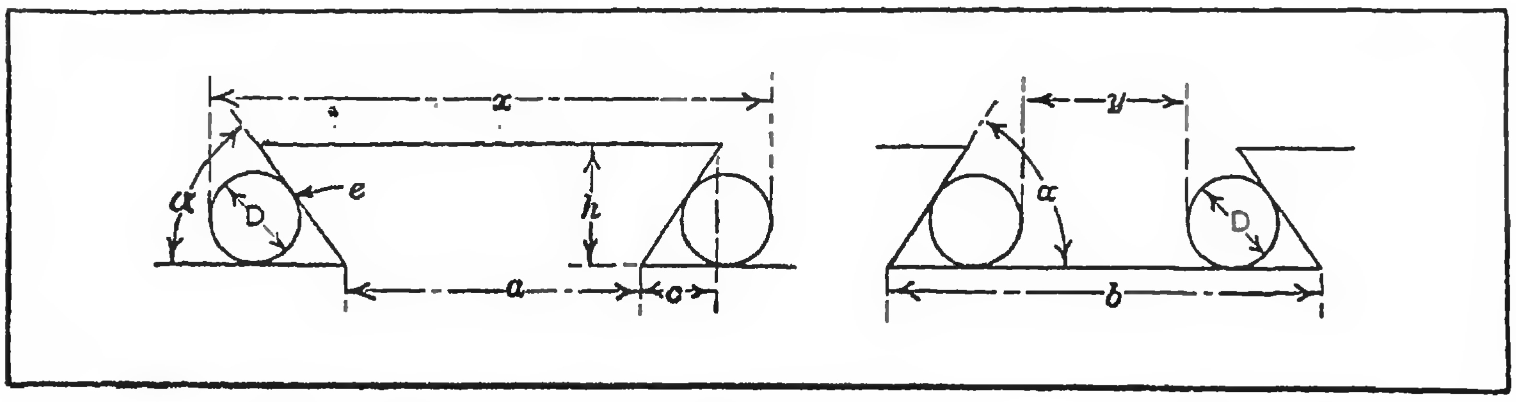
Double-Action Presses. The double-action type of power press is extensively used for drawing cylindrical or other circular shaped parts from flat sheet-metal stock. There are two slides which are operated independently; hence, the name *double action.* The outer slide is for operating the combined blanking die and blankholder of the double-action drawing die, whereas the inner slide operates the inner plunger or die which draws the part to shape. These slides may be actuated either by cranks, cams, or a toggle mechanism. The presses having a crank form of drive are much used in the manufacture of seamless drawn articles of comparatively shallow depth. The crank type of construction permits of much faster and smoother operation than is practicable with cam-driven presses.

Double-drawing presses differ mechanically from the ordinary double-action press in having three instead of two moving slides, and, therefore, might appropriately be called triple-action presses. The principal reason for this design is to save time and increase production by making two drawing operations on a single article with one stroke of the press or to draw and redraw, or redraw twice, in a single operation. This type is particularly adapted for articles that require more than one drawing operation to reduce them to the required dimensions.

Double-Contact Cam. A cam in which the follower has two points of contact, one on each side of the cam. This provides a positive motion for the parts connected to the follower.

Dovetail Joint. See Joints used in Patternmaking.

Dovetail Slide. This is a type of slide used extensively in machine construction. It has angular sides which interlock with the grooved part of the mating base or slide. As a general rule,



Cylindrical Rod Method of Measuring Dovetail Slides

a gib is inserted between the slide and the grooved member, to provide means of taking up all play.

Dovetail slides which must be machined accurately to a given width are commonly gaged by using pieces of cylindrical rod or wire and measuring as indicated by the dimensions x and y in the accompanying illustration. In order to obtain dimension x for measuring male dovetails, add 1 to the cotangent of one-half the dovetail angle a, multiply by diameter D of the rods used, and add the product to dimension a. To obtain dimension y for measuring a female dovetail, add 1 to the cotangent of one-half the dovetail angle a, multiply by diameter D of the rod used, and subtract the result from dimension b.

Dovetail Slide Angles. The angle a (see illustration accompanying preceding paragraph) does not conform to any fixed standard and varies in practice, usually from 45 to 60 degrees. The 60-degree slide or dovetail is easier to make and fit accurately than a smaller angle, such as 45 or 50 degrees, and consequently, the 60-degree slide is preferred by most manufacturers.

Any wedging action tending to open a dovetail slide, is greater with the 60-degree angle than with smaller angles, the ratio being 173 to 100 for 60-degree and 45-degree slides, respectively. A 45-degree slide, however, requires greater width when properly designed than a 60-degree slide, which usually is important since the slide width is somewhat limited. Within given limits a stronger 60-degree slide can be designed than one of 45 degrees, and the somewhat greater wedging force tending to open the 60-degree slide is ordinarily of little practical importance.

Dowel Pins. Dowels are used either to retain parts in a fixed position or to preserve alignment. Under normal conditions a properly fitted dowel is subjected to shearing strain only, and this strain occurs only at the junction of the surfaces of the two parts which are being held by the dowel. It is seldom necessary to use more than two dowels for holding two pieces together and frequently one is sufficient. For parts which have to be taken apart frequently, and where driving out of the dowels would tend to wear the holes and thus loosen the dowel, and also for very accurately constructed tools and gages which have to be taken apart, or which require to be kept in absolute alignment, the taper dowel is preferable. As applied to average machine work, the taper dowel is most commonly used but the straight dowel is given the preference on tool and gage work, except where extreme accuracy is required, or where the tool or gage is to be subjected to rough handling, and knocking about would be likely to shift the doweled parts.

Dowels, Embossed. See under Rivets, Cold-formed.

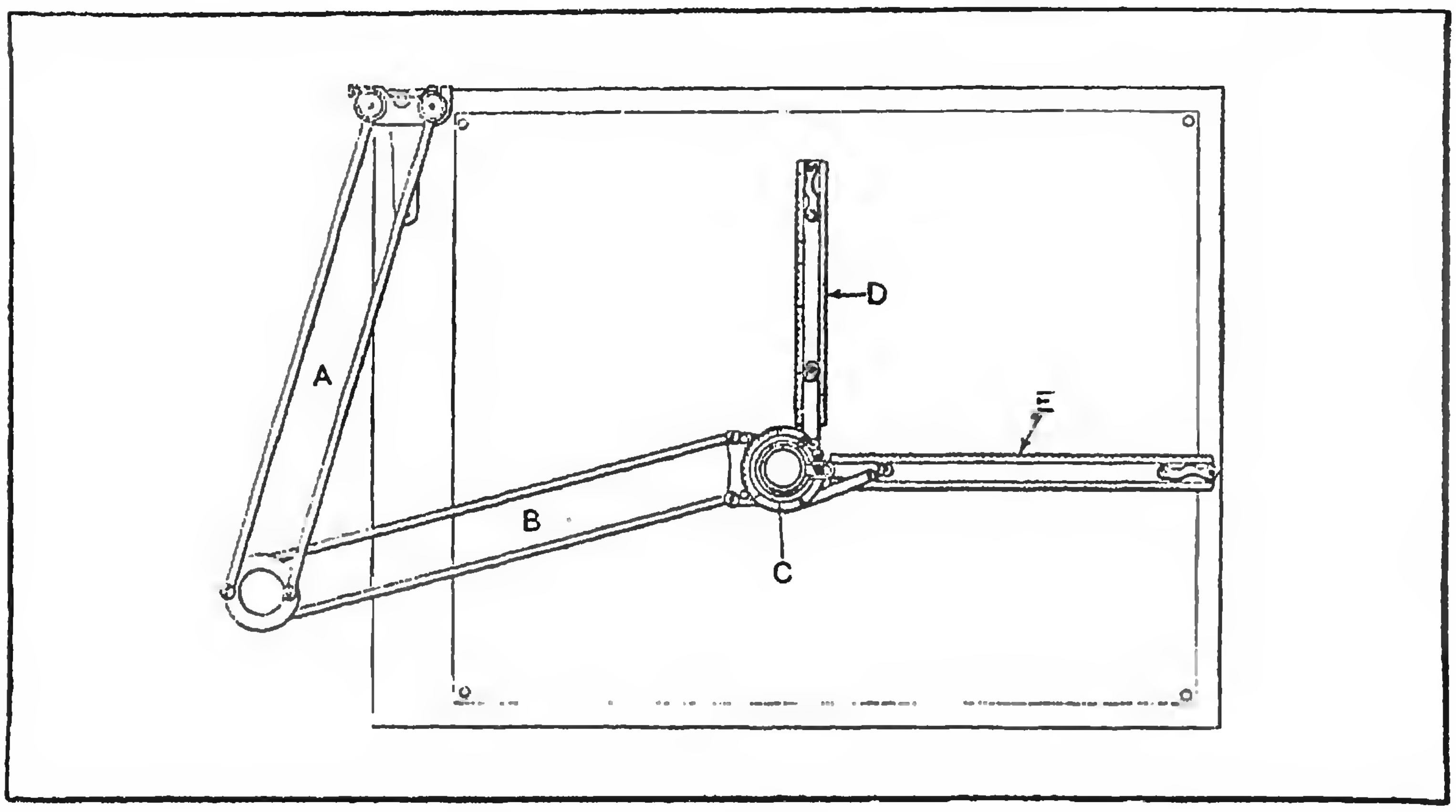
"Dowmetal" Alloys. This is a trade name applied to magnesium alloys. See Magnesium Alloys.

Doyle Rule. The Doyle rule which follows is employed for finding the board measure of logs: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply the result by the length of the log in feet; usually the diameter inside of the bark at the small end is measured.

Draft. See Forced Draft; Induced Draft; Mechanical Draft.

Drafting Machines. The device known as a *drafting machine* is employed to facilitate the making of drawings, by taking the place of T-square, triangles, protractor, and scale. It consists of two parallelograms *A* and *B* (see illustration), a protractor *C*, and two scales *D* and *E*, set at right angles to each, these scales being used as ruling edges. The two parallelograms are joined together in such a way that when the upper end of one of them is fastened to the drawing-board, as indicated, the protractor and

ruling scales will have a parallel motion on the drawing. This arrangement permits the zero of either of the ruling edges to be instantly placed on any point of the drawing, so that lines may be drawn and measured off at the same time. The protractor, placed where the two scales or rules join, permits the square formed by the rules to be set at any angle, and after that the ruling edges may be moved about the board with the same parallel motion as when set as shown in the illustration. This feature is of great importance in structural work, where a great many parallel lines must be drawn at angles other than horizontal or vertical. Drafting machines are made for practically all kinds of applications, and for both horizontal and vertical drawing-boards.



Universal Drafting Machine

Draft on Patterns. Draft is a tapering of all the vertical faces of a pattern to permit its removal from the sand without excessive rapping on the part of the molder. There is no rule fixing the amount of draft to give a pattern, but it is a good plan to allow as much draft as possible without distorting the pattern; this may vary from 1/32 to 3/16 inch or may even be as much as 1/4 inch per foot of height. The draft always extends away from the pattern face, or larger side of the pattern. Very small patterns and those of larger sizes to be used in molding machines are often made without draft.

Draw-Bar Pull. This term applied to locomotives represents the amount of power actually exerted at the draw-bar, and it is somewhat less than the tractive force. See Tractive Force.

Draw-Benches. Two types of machines are generally used for drawing shafting and screw stock. The first of these is known as the "straight draw-bench," on which a straight rod is drawn through the die by means of tongs on a head which travels in a straight line along the draw-bench, power being furnished by an endless sprocket chain or by hydraulic pressure. The second type is the bull-block machine, on which the rod is in the form of a coil that is carried on a reel at one end of the machine; the end of this rod is pointed and threaded through the drawing die, and gripped by tongs carried on a second reel, which rotates in such a way that the rod is drawn through the die and wound up on the second reel.

The draw-benches, by means of which the tubes are drawn, are of different sizes for working on heavy or light stock. The mechanism of the draw-bench is simple and powerful. A typical design that handles tubes up to 20 feet in length consists of a "bench" about twenty-five feet long, within which is an endless sprocket chain of very heavy pattern that passes over a sprocket at the driving end and an idler at the head of the machine. The drive is through compound gearing to the sprocket at the end of the draw-bench, and the sprocket chain runs continuously. The speed at which the chain travels is about sixty feet a minute for the smaller sized machines, but slower in the larger machines. At the forward end of the machine, the frame runs into a very heavy head, against which the dies are held when drawing the tubes. Supported centrally in the head is a steel plate with a clearance hole large enough for the tubes to pass through. Directly against this clearance plate, the dies are held loosely while the tubes are pulled through them. This drawing operation is accomplished by a carriage, drawn away from the head of the machine by means of a hook that may be caught between the chain links. On the forward end of this carriage is a pair of gripping jaws that catch the end of the tube when it is started and pull it through the die. At the end of the stroke, the hook is lifted out of the chain and the carriage returned by hand.

Draw-Filing. When a file is held at each end and the motion is sidewise rather than in a lengthwise direction of the file, this is known as *draw-filing.* With this method of filing, the metal is removed more slowly than by cross-filing, provided the same kind of file is used in each case. The surface is left smoother, however, if the draw-filing is properly done, as the scratches are closer, owing to the shearing cut taken by the file teeth.

Draw-In Chuck. This is a collet type of chuck generally used on tool-room lathes, turret lathes, bench lathes, and similar machine tools, for holding bar stock or tools. The end of the chuck

is split so that it can be forced together, to clamp over the stock or tool held in it. The outside of the end is conical, and fits into a conical chuck closer, so that by pulling back the chuck, the chuck closer forces the split chuck to clamp.

Drawing Dies. Drawing dies are used for drawing parts from flat stock into cylindrical and various other shapes. There are several different classes of drawing dies, including plain drawing dies, combination dies, double-action dies, and triple-action dies. The *combination type* of die is one in which a blanking die and either a drawing or forming die are combined so that the blank is cut out and drawn or formed to shape in one stroke of the press. Owing to the construction, a combination die can be used in a single-action press, or one having a single slide. In most cases, articles made in combination dies are in the form of shallow cups, etc., such as can tops and bottoms, pail bottoms and a variety of similar parts which frequently are not over ¼ inch in depth. Dies of this class are also used for deeper articles, such as boxes and covers for blacking, salve, tobacco, etc., with depths up to about one inch.

Double-action dies are so named because the blanking and drawing punches have independent movements which are derived from the two slides of a double-action press; hence, the name of the die, in this case, indicates the type of press in which it is used. A *triple-action die*, as the name implies, is one having three independent movements. This class of die is used to produce articles requiring three operations, such as cutting or blanking, drawing, and stamping or embossing. Triple-action dies are especially adapted for such work as drawing and embossing lettered covers for blacking boxes, baking powder cans, covers for lard pails, and also for articles such as seamless sardine boxes, etc.

After cups have been drawn in either a plain or double-acting drawing die, what are known as *redrawing dies* are often used to reduce the diameters of these comparatively shallow cups, and at the same time increase the depth or length, thus forming a shell. Some redrawing dies do not differ essentially from an ordinary plain drawing die.

Drawing Sizes. While the practice differs to some extent in different manufacturing plants, it is fairly common practice to use drawings 24 by 36 inches in size as the standard sheet. For smaller work, this is divided into half-sheets, 18 by 24 inches; quarter-sheets, 12 by 18 inches; and eight-sheets, sometimes called "sketching" sheets, 9 by 12 inches. These dimensions of standard sheets have been adopted because it is possible to obtain rolls of drawing-paper, tracing cloth, and blueprint paper in such

widths that sheets of the sizes mentioned can be conveniently cut from them without waste.

American Standard Drawing Sizes. Sizes recommended by the American Standards Association for drawing paper and cloth are, in inches: 8½ by 11; 11 by 17; 17 by 22; 22 by 34; 34 by 44. These sizes are based upon the commercial letter size of 8½ by 11 inches, which is in general use in the United States.

Drawing Steel. Steel is "drawn" or tempered by reheating it after hardening to some temperature below the critical temperature range and then cooling the steel. This heat-treatment is often referred to as drawing, but the term tempering is preferable. The object of tempering cutting tools is to reduce the brittleness of the hardened steel and increase its toughness sufficiently to withstand the shocks incident to working conditions. See Tempering.

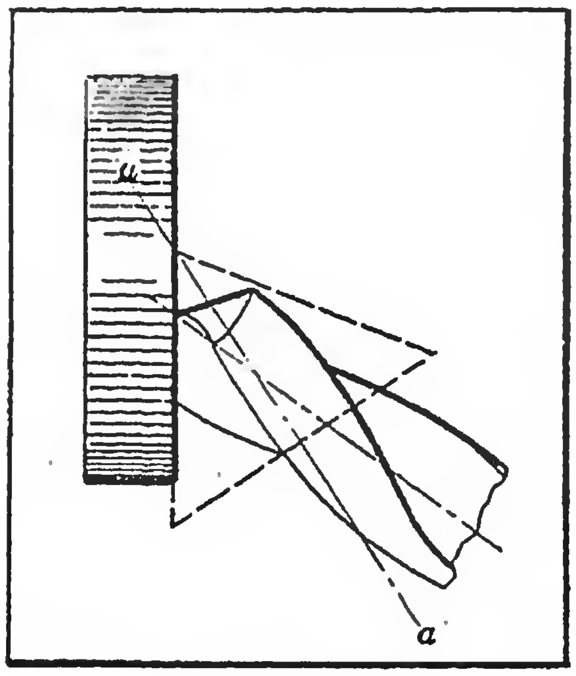
Drift Pin. A round tapered steel pin which is driven into two mismatching holes in two parts in order to line up other holes in the two parts. This facilitates placing rivets in the holes and riveting the two parts together.

Drill Grinding. As the angle between the cutting edges of a drill is increased, the pressure required for feeding the drill downward through the metal, becomes less, but the length of each cutting edge is increased, with the result that more power is required to turn the drill. An included angle of 118 degrees (59 degrees between the cutting edge and axis) is believed by some to equalize the thrust and torsion to the best advantage, while others advocate more acute angles.

Theoretically, the *clearance* of a drill should be just enough to permit the drill to cut freely, because excessive clearance weakens the cutting edges. The clearance angle often is about 12 degrees at the circumference of the drill when the grinding is done by hand and without a decided increase in clearance toward the point. When soft metal is to be drilled and heavier feeds are possible, the angle of clearance may be increased to 15 degrees, whereas for hard material, such as tool steel, for example, the amount of clearance should be diminished, as a fine feed must necessarily be used and a strong cutting edge is required. These clearance angles of 12 or 15 degrees are much larger than are required at the periphery, in order to increase the angle adjacent to the point which otherwise would have insufficient clearance. With one type of drill grinder, the clearance angle at the periphery usually is about 7 degrees, because special provision has been made for increasing the angle toward the point.

Drill Grinding Machines. Twist drills should be ground in specially-designed drill grinding machines to obtain the best results. The two cutting edges should have the same inclination and come into contact with the work throughout the entire length at the same time, and the clearance surface back of the cutting edge should vary from the point of the drill, where it is greatest, to the periphery, where it is the least acute. A method of obtaining this varying clearance, which is employed in connection with many drill grinding machines, is illustrated by the accompanying diagram. The rotation of the drill, when grinding, is about an axis *a–a* which is inclined from the face of the grinding wheel somewhat less than the axis of the drill. When a drill is ground in this way, the end is given a conical surface, the apex of the cone being above the point of the drill, as indicated by the dotted lines.

With one type of drill grinder, the clearance toward the drill point increases at such a rate that 7 degrees, or even less, at the circumference is possible without interference anywhere along the cutting edges when the drill feed per revolution is at the maximum likely to be employed. The object is to obtain maximum support or strength for the cutting edges and also reduce the feeding pressure. In grinding, the drill rotates continuously about its own axis at a constant rate of speed. The drill is held in a two-jaw chuck which is rotated by gearing. This chuck and the drill have a rotary motion. The grinding is done by the flat face of a ring-shaped wheel. The wheel-spindle and wheel have a slight planetary or eccentric motion which imparts to the wheel the equivalent of a traversing movement. The wheel also has an endwise motion governed by a cam. This cam is so shaped and located that the inward motion of the wheel toward the drill starts when a drill lip is horizontal. As the wheel advances, it forms a helical clearance surface on the drill lips. The continued advance of the wheel and the slowing up of the traversing movement at the end of its travel, causes the wheel to form a hollow or concave surface back of the cutting edge adjacent to the point. The result is an increased rake at this part of the chisel point where there is slight cutting, thus reducing the end or feeding pressure.



Drill Grinding

Drill Heads. Single-spindle drilling machines are sometimes equipped with attachments commonly known as *drill heads,* which

are equipped with two or more spindles for drilling, simultaneously, whatever number of holes the head is designed for. A drill head of typical construction has a taper shank which enters the drilling machine spindle and drives all of the spindles of the attachment through spur gearing. Drill heads may be divided into two general classes, namely, the adjustable and the non-adjustable types. The adjustable heads vary in regard to the kind or range of adjustment that is possible. The straight-line adjustable drill head has all of the spindles in the same vertical plane, the adjustment in this case enabling the center-to-center distances to be varied, according to the work. A drill head having radial adjustment is a type of multiple-spindle drilling attachment which may be adjusted for drilling or tapping operations on circles of various diameters.

Drilling Deep Holes. One method of drilling deep holes is to provide a rotary motion for the work and a feed motion for the drill; then if the point of the drill does not run true, it will be carried around by the work in a circle, thus tending to bend the drill in various directions. The drill is by this action forced back into the path of "least resistance," as it is evident that the bending action, being exerted on the drill in all directions, will tend to force the point back in alignment with the axis of the work where there will be no bending action.

Step-by-Step Method: This method involves the use of a hydraulically operated head which automatically feeds the drill to a predetermined depth, withdraws it completely from the hole, and again advances it to a predetermined depth. This cycle is repeated until the hole has been drilled entirely through, or, in the case of a blind hole, to the required depth. With each withdrawal of the drill, the hole is cleared of chips and a copious stream of coolant fills the hole, cooling both tool and work. With this method, drills may be used that have flutes extending only a small fraction of their length and that have thicker web sections than standard drills, therefore possessing greater strength. The depth to which the drill is fed into the work with each forward stroke of the hydraulic head is so controlled that the forward movement is completed before excessive thrusts occur and before the hole becomes clogged with chips. Only a small quantity of chips is produced at each forward drill movement, and it is for this reason that drills can be used having flutes extending only a fraction of their total length and with a thicker web than standard drills. The greater drill rigidity and strength provided by the larger cross-sectional area of the fluted end enables the drills to resist heavy thrusts in any direction.

Generally speaking, the practice is to drill to a depth equal to the drill diameter at each step. This hydraulic method of

step-by-step drilling is applicable in the automotive industry for producing long holes of small diameter in crankshafts, connecting-rods, carburetor parts, etc.

Drilling Machines. Drilling machines or "drill presses," as they are often called, which are used for drilling holes in machine parts, are made in many different types designed for handling the various classes of work to the best advantage, and the different types are also built in a great variety of sizes, because the most efficient results can be obtained with a machine that is neither too small nor too large and unwieldy for the work which it performs. Drilling machines of different designs are classified in various ways.

The *upright drilling machine* is the type most commonly used, and the name applied to this class indicates that the general design of the machine is vertical, and also that the drill spindle is in a vertical position. All drilling machines, however, which have vertical spindles and are arranged vertically, are not classified as upright drills.

The *radial drilling machine*, which is another very common design, has a vertical spindle, which is carried by an arm that may be swiveled about a vertical column. The distinguishing feature of this machine, however, is the radial adjustment of the arm about the column, which adjustment, in conjunction with the traversing motion of the drill-spindle head along the arm, makes it possible to readily locate the drill in any position within the range of the machine, which is a decided advantage when drilling heavy parts that could not be shifted easily. Machines of this class, therefore, are said to be of the radial type, because the radial or swiveling adjustment of the arm is the characteristic feature.

The *sensitive drill* is another vertical or upright design, but it is classified as sensitive because it is a comparatively small machine of light construction, which possesses sensitive qualities which are of value in drilling delicate work.

The *multiple-spindle type*, which is built in both vertical and horizontal designs, is given a name which is self-explanatory. Some drilling machines equipped with multiple spindles are known as *gang drills*. The term "gang drill" is generally applied to a vertical design practically consisting of several machines combined in one unit, and with the spindles all in the same vertical plane. Machines of this general design are also referred to as multiple-spindle drills, by many manufacturers. Drilling machines, however, having spindles which are arranged in a group so that they may be adjusted according to the respective posi-

tions of the holes, whether in a straight line, on a circle, or irregular as to location, are especially known as multiple-spindle types.

Some drilling machines having more than one spindle are named according to the number of spindles, as, for example, a four-spindle sensitive drilling machine, etc. In other cases, a special design of machine having several spindles is classified according to the work for which it is intended, as, for instance, a staybolt drilling machine, a locomotive frame drilling machine, a rail drilling machine, etc. Very heavy and powerful drilling machines of the vertical or upright type are also referred to as "high-duty" or "heavy-duty" type drilling machines, because they are capable of very rapid drilling.

Some drilling machines are equipped with a turret which carries the necessary tools, and is indexed to locate these tools in the working position the same as the turret of a turret lathe. There are two general types of these machines: one has a turret which revolves about a horizontal axis with the tools in a vertical plane, and the other, a turret which revolves about a vertical axis. Machines of this type are adapted to work requiring successive operations, such as drilling, reaming, counterboring, etc.

Drilling Machine Size. The size of an upright drilling machine is equal approximately to twice the distance from the drill spindle to the column. A 28-inch drilling machine, for example, will drill to the center of a 28-inch circle or possibly to the center of a 29-inch circle. The size of a radial drilling machine represents the maximum distance from the column to the center of the spindle or the greatest radius at which the drill spindle can be set.

Drill Press. This term is often applied to metal drilling machines in general, evidently because the drill is pressed or forced through the metal as it revolves. See Drilling Machines.

Drill Rod. Small diameter, high-carbon tool-steel rods are generally referred to as *drill rod.* Drill rod is either polished or unpolished. Carbon-steel drill rod is kept in stock by steel manufacturers in all sizes, from 1/64 to 1½ inches, by 64ths, and, in addition, the standard "letter" and "number" sizes for drills are available. Square drill rod is kept in stock for all sizes between 1/16 and ½ inch, by 32nds. High-speed steel drill rod is kept in stock from 1/16 to ½ inch, by 64ths, and for all "letter" drill sizes, and for "number" drill sizes from 1 to 52, inclusive. Some of the steel manufacturers work to a limit of 0.00035 inch above and below the specified sizes for diameters smaller than 1 inch,

and to a maximum limit of 0.0005 inch above or below the specified size, for sizes between 1 inch and 1½ inches.

Drills. A number of different tools used in the machine shop are classified under the head of drills. The most common type of drill for ordinary drilling in solid metal is the well-known twist drill. These drills, as designed for drilling in solid metal, are provided with two grooves or flutes. When a drilled, cored or punched hole must be enlarged, a three-groove drill or a four-groove drill is commonly used. These three- and four-groove drills have flat ends and cannot be used for drilling in solid metal.

In drilling rather deep holes, it may be difficult to supply the point of the drill with the required amount of oil or cutting compound due to the tendency of the chips to carry the fluid back with them before it reaches the bottom of the hole. To overcome this difficulty, oil-hole drills may be used. This type is provided with internal holes or ducts through which the cutting fluid can be carried right to the drill point. The fluid and chips escape through the flutes of the drill in the usual manner.

Drill Shanks: The shank of a drill, or that part which is held in a socket, spindle or chuck, may be either straight (cylindrical) or tapered. If the shank is tapered, it conforms to the Morse standard. Morse standard tapers include eight different sizes ranging from No. 0 to 7. Five or six of these sizes are used for a range of taper shank drill diameters varying from ⅛ inch to 3 or 3½ inches, which is the usual commercial range. This means that each taper number includes quite a range of diameters.

Drill Sizes: There are three methods of designating the sizes of twist drills. In many cases, the actual diameter is given. Numbers are used to represent a certain range of small drill sizes, and a range of somewhat larger diameters is indicated by the letters of the alphabet. Twist drills in fractional sizes are made in a large range of sizes. To illustrate, one prominent manufacturer makes high-speed twist drills in sizes from ⅛ to 1¾ inches varying by 64ths, and by 32nds up to 2¼ inches and then by 16ths up to 3½ inches. In the 26 letter size drills, size A is the smallest and represents a diameter of 0.234 inch. The largest size Z is equivalent to a diameter of 0.413 inch and the difference between consecutive sizes varies from 0.004 to 0.014 inch. In the numbered sizes, the No. 1 size equivalent to a diameter of 0.228 inch is the largest, and the No. 80 size equivalent to a diameter of 0.0135 inch is the smallest.

Sizes of Straight Shank Drills: There are, in general use, four different series of straight shank drills. One series is known as the *taper length* because these straight shank drills have the

same total length as the taper shank drills. These straight shank sizes are the same as the taper shank sizes but the range of diameters is somewhat less and usually is from ⅛ to 2 inches.

Straight shank twist drills in the *jobbers length,* or short length, are a small series ranging from 1/64 or 1/32 up to ½ inch in diameter. Straight shank twist drills are also made to conform to both the wire gage sizes and the letter sizes. The letter sizes are also made with taper shanks.

Drill Steels: The steels used for twist drills include plain carbon tool steel, finishing steels, high-speed, and super-high-speed steels.

Carbon Steel: Notwithstanding all of the developments made in tool steels, carbon steel drills fill a definite need and find widespread application. A typical analysis of the carbon tool steel commonly used for drills is as follows: Carbon, 1.20 per cent; manganese, 0.25 per cent; phosphorus, 0.015 per cent; sulphur, 0.015 per cent; and silicon, 0.20 per cent. Some drill manufacturers prefer to add chromium up to approximately 1 per cent. This increases the hardness penetration in the larger sizes and permits of oil quenching in the smaller sizes. Other drill steels contain up to 0.25 per cent of vanadium to add toughness and refinement of grain.

High-speed Steel Drills: Manufacturers of twist drills generally use practically the same analysis of high-speed steel. This analysis is approximately as follows: Carbon, 0.70; tungsten, 18; chromium, 4; and vanadium, 1 per cent. This steel is generally referred to as an 18–4–1 steel. Steels with somewhat over 0.70 per cent carbon are generally used for small drills, while slightly less than 0.70 per cent carbon is used for the larger sizes. The 14 per cent tungsten high-speed steel is no longer used for drills. High-speed steels containing no tungsten, but instead approximately 7 per cent of molybdenum, have given very good results. If the conditions are such that carbon steel drill speeds are sufficient for the purpose, high-speed steel drills are not economical to use, because the difference in performance, as compared with the carbon steel tool, does not compensate for the difference in price.

Cobalt High-speed Steel: By slightly increasing the percentages of carbon and of the alloying metals, and by adding up to 12 per cent of cobalt and 1 per cent of molybdenum, a super-high-speed steel is produced capable of withstanding higher cutting temperatures. There are several cobalt high-speed steel drills on the market that find wide application in drilling hard metals which are beyond the capacity of ordinary high-speed drills. In resisting the action of abrasion, the cobalt high-speed steel drills,

with their higher carbon and alloy content, are superior to those made from ordinary high-speed steel, but they cannot be compared with tungsten-carbide tipped tools. The addition of cobalt to high-speed steel increases the red hardness and the resistance to tempering. In other words, cobalt high-speed steel drills can be subjected to higher cutting temperatures without destroying the edges.

Drills, Angular Hole. Special drills have been developed for drilling square, hexagonal, octagonal and other angular holes. Tools for this work have been made in several different forms. but the principle of operation is to rotate a drill of special form in a guide which has the same shape as the hole to be cut. The drill is mounted in a special floating chuck which allows sufficient movement so that the cutting edges of the tool can generate the required shape of hole. The lands of the drill successively come into contact with the guide and act as cams which cause the cutting edges of the drill to follow the desired path. Drills used for this work only cut with the front edges, there being no cutting edges along the side. These angular drills have been used successfully for drilling steel, cast iron, brass, aluminum and various non-metallic substances. Ordinarily, in using tools of this type, it is advisable to first drill a round hole which is about 1/8 inch smaller in diameter than the width across the sides of the square, hexagonal, or other hole. By thus removing most of the metal, the angular drill may be operated at higher speed and with less strain on the tool.

Drill Speeding Attachment. In drilling small holes on a machine which is not arranged for high speeds, the drill revolves too slowly and the operation requires much more time than would be necessary if the drill were operated at the proper speed. Many drilling machine attachments have been designed for increasing the speeds of small drills. These are often called "drill speeders." These attachments are applied to the end of the drill spindle, and, by means of suitable gearing, the auxiliary spindle in which the small drill is held is rotated much faster than the main spindle of the machine.

Drill Speed Regulator. This is an attachment which is applied to the end of the drill spindle for driving different sizes of drills at the correct speed by automatic regulation. A different collet is provided for each size of drill which is used, and the speed changes are obtained by having a driver on each collet located in a different position, so that each one engages the proper gears in the head. With this arrangement, the speed is regulated automatically in accordance with the size of the drill.

Drills, Portable Air-Driven. Pneumatically-operated drilling machines of the portable type are not only used for drilling, but for reaming, tapping, flue rolling, wood boring, and as motors, especially for driving portable tools such as valve-setting and cylinder-boring machines in locomotive repair shops. Pneumatic or "air" drills, as they are often called, are made in reversible and non-reversible designs. The type commonly used is driven by an air motor of the reciprocating piston type, which is contained within the casing of the machine. The pistons are single-acting and impart rotary motion to the crankshaft by suitable connecting-rods. This crankshaft, in turn, drives the main spindle of the machine through gearing which reduces the speed and gives the necessary increase in power. What is commonly known as the *close-quarter air drill* is designed for use in corners or narrow places where a drilling machine of ordinary size cannot be used.

Drills, Portable Electric. A portable electric drill is a compact semi-enclosed electric motor in combination with mechanical features so designed and constructed as to be applicable for drilling or reaming in wood or metal more or less intermittently. Portable electric drills are generally listed according to their drill capacity, and sometimes this is definitely specified as the maximum size drill that the motor has sufficient power to drive through steel. Many electric drills have "universal motors" built to operate on either direct or alternating current, the standard frequency for alternating current being 60 cycles, although some of the universal motor types will operate at 25, 30, 40 or 50 cycles, as well. Some drills are built to operate on 180-cycle current for use where a frequency changer is installed and these are claimed to have the advantage of lighter weight as compared with the same sizes in the standard types. Electric drills are made either standard, light duty, or heavy duty, and the weight varies accordingly. Electric drills are equipped with a drill chuck for holding straight shank drills, or a spindle with a standard tapered hole for taper shank drills. The drill chuck or drill spindle is usually driven by reduction gearing from the motor armature shaft. These spindles are located so as to provide what is termed straight-line or close-quarter construction, so as to permit the drilling of holes as close to a wall as possible.

Drive Pipe. The name applied to a pipe used in conjunction with a hydraulic ram. See Hydraulic Ram.

Drivers or Dogs. See Dogs or Drivers.

Driving Fit. When a plug or a shaft is made slightly larger than the hole into which it is to be inserted and the allowance is such that the parts can be assembled by driving, this is known as a *driving fit*. Such fits are employed when the parts are to

remain in a fixed position relative to each other. The allowance for a driving fit depends upon the length of the bearing surface, the diameter of the hole, the smoothness of the surfaces and the thickness and kind of metal surrounding the hole.

Drooping Characteristic. This is a term used in connection with electrical machinery when the voltage varies inversely with the load.

Drop Forging. Forgings produced in dies by a falling hammer which is lifted by mechanical means and known as a drop-hammer, are called *drop-forgings.* The shape of the forging is cut out or "sunk" into dies, so that often a single blow of the hammer on the dies shapes the heated iron bar to the desired form. A drop-forging can be produced with a tolerance of 1/32 inch as an ordinary commercial limit for small work, although it is possible, by careful forging and supplemental restriking, and providing the forging is fairly small, to produce work within a few thousandths of an inch. The degree of accuracy possible in drop forging is, however, very seldom realized, and for work within very fine limits it is necessary to have multiple dies; that is, one or more pairs of dies for roughing-out, and one or more pairs of dies for the finishing operations. *String forging* is the most economical way of drop-forging certain small pieces. By string forging is meant the forming of small pieces in a string, without cutting off each piece separately after forging.

Fin and Flash: Excess stock that is squeezed out of the impression into the narrow space between the upper and lower sections of a drop-forging die, is called the "fin." To take care of this metal that is crowded out of the impression, each die is relieved around the impression by milling a flat, shallow recess, about 1/64 inch deep and ⅝ inch in width all around the impression. These dimensions are for dies of average size; in larger dies, the recess or "flash," as it is called, would be a little deeper and wider. Both the upper and the lower dies are flashed in this manner. In addition, the upper die is back-flashed; that is, there is, a deeper recess, sometimes called the "gutter," milled around the impression at a distance of ¼ inch from the impression at every point. The back-flash is 3/64 inch deep, and acts as a relief for the excess metal after it has squeezed through the flash proper. Only the finishing impression is provided with flash and back-flash. The fin is trimmed from the forging by means of trimming dies, when the forging is either hot or cold, depending upon the size and shape.

Drop-Forging Die Materials. The material from which drop-forging dies are made is usually either a high-grade open-hearth carbon steel or an alloy steel containing certain percentages of

nickel and chromium, although other alloys are used in special cases. When drop-forging dies are made from open-hearth steel a 0.60 per cent carbon steel is generally used. In some cases, however, steel as low as 0.40 per cent carbon and as high as 0.85 per cent carbon is used, but few shops use anything but 0.60 per cent carbon steel for the general run of work. If a low-carbon steel is used, a special hardening treatment is required, which outweighs any saving in the price of the steel. The high-carbon steels make good dies, but except in special cases, there is no necessity for using so high-priced a steel. The average 0.60 per cent carbon steel die, if properly hardened, should last for from 15,000 to 40,000 forgings, and sometimes as many as 70,000 forgings are made from one set of dies. In making dies for large forgings, it is often considered advisable to use 0.80 per cent carbon steel for the dies, and not to harden them. This obviates the danger of "checking" or cracking in hardening, and the steel, unhardened, is hard enough to resist the tendency to stretch.

Special *chrome-nickel steel* has been found particularly suitable for producing drop-forgings from a high grade of material. The development in the use of chrome-nickel steel has been due largely to the demands of the automobile industry, in which there are used a great variety of intricately shaped drop-forged parts made from dense fine-grained alloy steels of various compositions.

Cast-steel dies are sometimes used, but the castings must be sound and free from blow-holes. The advantage of casting the die impressions over sinking them is in the saving of time in manufacture, and more especially in the possibility of producing more intricate shapes. Cast-steel die-blocks are not recommended, however, unless the design of the forging demands that the impressions be cast. On the lighter classes of drop-forgings, particularly if there are only a few to be made from one impression, *cast-iron die-blocks* have been used with fair success. The finest grain of cast iron should be used in making drop-forging dies, and the structure of the iron should be homogeneous.

Drop-Forging Die-Sinking Machines. See Die-sinking.

Drop-Forging Dies, Lead Proof. In making drop-forging dies, it is customary to take a so-called "lead proof" from the impressions in the upper and lower dies, in order to make sure that the forging will have the right appearance when it comes from the dies, and to ascertain that there are no defective places in the impression. In making a lead proof, the impressions of both the upper and lower dies are cleaned and dusted with powdered chalk, the dies placed on end and clamped together with large C-clamps, and the heated lead slowly and evenly poured into the dies until it fills the impression and gate. As soon as the

lead has cooled, the dies are unclamped and the lead proof removed and examined. The lead proof will show any places on the forging that are not perfect, and, by weighing the lead, it is possible to ascertain the weight of the finished forging. Roughly speaking, two-thirds the weight of the lead proof will equal the weight of the finished forging. The shrinkage of lead is practically the same as that of steel, so that the finished forging will have practically the same dimensions as the lead proof.

Drop-Forging Steel. Generally speaking, low-carbon steels are more suitable for drop forging than high-carbon steels, because the latter are more difficult to work, there being a tendency to burn the steel on account of the high temperature to which it must be heated for forging. Nickel steels containing up to 3.5 per cent of nickel with about 0.30 per cent of carbon can be drop-forged with comparative ease. Nickel-chromium steels are difficult to drop-forge, particularly when the chromium content is over 1.3 per cent and the nickel content over 2 per cent, with the carbon content about 0.35 per cent; but these steels are very hard when heat-treated and have a very high tensile strength and elastic limit.

The great value of chrome-vanadium steels for drop forging lies in the fact that they can be very easily forged as compared with nickel-chromium steels. A suitable composition would be 1.2 per cent of chromium, 0.16 per cent of vanadium, and 0.32 per cent of carbon. This steel resists bending, torsional, impact, and vibrating stresses to a remarkable degree. Even the best steel may be ruined in drop forging in any one of three principal ways: 1. By careless treatment, in not carrying out the steel maker's instructions. 2. By incorrect treatment, due to ignorance of the properties of the steel used. 3. By working the steel at a temperature unsuitable for that particular brand of steel.

Drop-Hammers. Drop-hammers are so named because the hammer head is lifted by a power and then dropped upon the work. Hammers of this type are extensively used for producing drop-forgings, and are made in two general types, known as *board* drop-hammers and *steam* drop-hammers. With the former type, the hammer head, in its descent, is acted upon by gravity alone. whereas, in the case of a steam drop-hammer, the force of the hammer blow is greatly increased by the action of steam, which is admitted to the upper side of the hammer piston. In addition to the board and steam drop-hammers, there are what are known as "drop presses" or "drops," which are used for stamping and bending operations in connection with the manufacture of jewelry, silverware, etc. The crank-operated drop-hammer or "Peck lift"

was largely used for drop forging in the early days of the industry, but this type is now confined principally to stamping work and the silverware trade.

The first patent containing the basic principle of the *board drop-hammer* was taken out by Goulding & Cheney in 1861, the patent covering a drop-hammer that was lifted by means of a belt or board placed between rolls running in opposite directions. In the operation of a board drop-hammer, the hammer proper is raised by the action of frictional rolls which bear against a board that is attached to the hammer. The action of the hammer is controlled by a foot-treadle which is connected with board clamps. There are two of these clamps, one located at the front and the other at the rear of the board, which serve to hold the hammer in its upper position when the foot-treadle is released. When the foot-treadle is depressed, these board clamps are withdrawn, thus releasing the board and allowing the hammer to drop. By a greater or less depression of the treadle, variation in the force of the blow may be obtained regardless of the stroke or fall for which the hammer is adjusted. For instance, when the foot-treadle is pushed all the way down, the clamps are entirely released and the hammer drops freely, whereas, if the treadle is only partly depressed, there is more or less friction between the board and the clamps, and the fall of the hammer is retarded a corresponding amount. See also Steam Drop-hammers.

Drop Presses. The type of drop-hammer commonly known as a *drop press* has a base or anvil and two guides or uprights the same as a board drop-hammer, but the hammer proper is lifted by a different type of mechanism. A typical design of drop press is arranged as follows: The "lifter" or mechanism for raising the hammer is a separate unit. The hammer is connected to the lifter by a belt, the upper end of which is attached to a crank. This crank is driven by means of a pawl-and-ratchet mechanism which serves to elevate the hammer and then allows it to drop suddenly. The shaft carrying the ratchet is driven, through suitable gearing, from a shaft at the rear on which belt pulleys are mounted.

One of the advantages claimed for the lifting mechanism operating on the crank principle is that the hammer is started slowly from rest and the elevating speed is gradually increased, which relieves the mechanism from sudden strains, so that it is very durable. The lifter is designed to give a quick, snappy blow, although some of the older types were inferior in this respect. The mechanism is operated in practically the same way as a blanking or punching press, it being tripped by operating a foot-treadle. The height to which the hammer is raised and the force of the blow is regulated by changing the radial position of a

crank-pin, which is clamped to a toothed arm that provides fine adjustment and at the same time a firm grip.

Drop presses are extensively used in the manufacture of sheet-metal goods, hardware, cutlery, silverware, jewelry, etc., for bending, forming, and stamping operations. Special designs are also made for stamping or embossing and paneling large sheets of thin metal, such as are used by metallic cornice and ceiling manufacturers.

Drum Cam. A cam consisting of a cylindrical barrel into the cylindrical surface of which a groove is cut for the cam roller. Instead of a groove, the cam surface may be constructed by attaching guiding pieces on the surface of a cylindrical drum.

Drum-Wound Armature. A drum-wound armature for a generator or motor is one which consists of a core on which the conductors are wound in the form of coils which are placed in slots around the periphery of the core. There are two main types: The series drum or wave-wound armature, and the multiple drum or lap-wound armature.

In the original drum-wound armature, the coils were wound around the surface of the solid armature core in contradistinction to the ring type wherein the coil was wound around the shell of a hollow core so that part of the conductors were outside the core and part were inside.

"Drunken" Thread. A "drunken" thread, according to prevalent usage of this expression by machinists, etc., is a thread that does not coincide with a true helix or advance uniformly. This irregularity in a taper thread may be due to the fact that in taper turning with the tailstock set over, the work does not turn with a uniform angular velocity, while the cutting tool is advancing along the work longitudinally with a uniform linear velocity. The change in the pitch and the irregularity of the thread is so small as to be imperceptible to the eye, if the taper is slight, but as the tapers increase to, say, ¾ inch per foot or more, the errors become more pronounced. To avoid this defect, a taper attachment should be used for taper thread cutting.

Dry Analysis. A chemical analysis performed with dry reagents and the assistance of heat.

Dry Cells. The wet cell type of battery has been replaced largely by the "dry cell" which is more convenient, portable, requires less space, and is cheaper. The dry cell is usually made by placing a carbon cathode and depolarizing compound inside of a zinc cylinder, which forms the anode. The cathode and depolarizer are separated from the zinc by some absorbent material which is saturated with the electrolyte, usually a solution of sal-ammoniac

and zinc chloride; but sometimes the separation is made by mixing the electrolyte with some gelatinous body, which is poured into place while hot and, on cooling, forms a jelly. The top of the cell is then sealed to prevent evaporation. See also Batteries.

Dry Coloring. The term "dry coloring" relates to a method of coloring metals by the use of compounds which are mixed together, forming pastes that are applied with a brush. This paste is allowed to remain a number of hours and is then rubbed off. However, the *wet method*, that is, the process of dipping into a chemical solution, presents many advantages, both as regards economy of time and uniform results.

Dryers, Centrifugal. Centrifugal dryers are used for drying metal articles in connection with plating, japanning, etc., and also for cleaning the products from screw machines or other automatic machines. A centrifugal dryer consists of a perforated pan or basket which holds the work and is revolved usually from 1000 to 1500 revolutions per minute, while heated air is circulated through the parts being dried. One type of dryer has a steam coil for heating the air which is forced through the contents of the basket by a fan or blower. Another type contains an electrically-heated grid for supplying the heated air. The drying pan or basket may be revolved either by belt or a direct-connected motor. The drying operation may require from 2 or 3 minutes up to, say, 5 to 7 minutes, depending upon the nature and shape of the product.

Dry Measure. One bushel (U. S. or Winchester struck bushel) = 1.2445 cubic feet = 2150.42 cubic inches; 1 bushel = 4 pecks = 32 quarts = 64 pints; 1 peck = 8 quarts = 16 pints; 1 quart = 2 pints; 1 heaped bushel = 1¼ struck bushel; 1 cubic foot = 0.8036 struck bushel; 1 British Imperial bushel = 8 Imperial gallons = 1.2837 cubic feet = 2218.19 cubic inches.

Dry Process. In assaying, "dry process" is a method for ascertaining the quantity of metals in ores. The process consists mainly in oxidizing the ores by the agency of heat. It is also known as the pyrometallurgical process.

Dry Sand Core. This is a part of a foundry mold, inserted in the mold cavity in such a way as to form either a hole or a recess in the casting. It is made from coarse sand, free from clay, the sand being mixed with a bond or binder until it is of about the consistency of heavy flour dough, and then baked in a core oven until it is dry and hard.

Ductile Iron. See Nodular Cast Iron.

Ductility of Metals. The ductility of metals refers to their susceptibility of being drawn into wire. The finer the wire that

can be drawn from a given metal, the more ductile it is. Of the metals, platinum is one of the most ductile. Next in order, of the more common metals, come silver, iron, copper, gold, aluminum, zinc, tin, and lead. The ductility is closely related to the property of metals known as "elongation."

Duraloy. Duraloy is a trade name applied to chrome iron alloys containing a larger percentage of chromium than ordinary stainless steel, the chromium content ranging from 27 to 30 per cent. This alloy was developed originally for high temperature installations as it resists oxidation at temperatures up to about 2100 degrees F. Duraloy has unusual resistance to most corroding elements and particularly to nitric acid, most of the organic acids and to the acid water found in the coal fields. Castings containing 16 to 18 per cent chromium resist corrosion practically the same as those of high chromium content, but are not satisfactory for high-temperature installations. This alloy is used in the form of castings, forgings, bars, sheets, plates, wire, and fabricated forms. The carbon content depends upon the application and also upon the form of the material. For example, the carbon in rolled products is kept low to insure ductility, and in castings it is varied to give either satisfactory machining qualities or extreme hardness and resistance to abrasion. The strength of duraloy varies with the analysis, treatment, and form, but in general the ultimate tensile strength in pounds per square inch varies from 40,000 to 50,000 for cast products, and from 80,000 to 90,000 for rolled material. The strength at high temperatures can only be determined accurately by tests extending over long periods, because fatigue is a very important factor; however, duraloy has a tensile strength at least of 3500 pounds per square inch when subjected over a long period to 1650 degrees F.

Duralumin. Duralumin is an aluminum alloy which is somewhat heavier than pure aluminum but has practically the strength of steel; hence, this is an alloy of great value where lightness combined with strength is required, as, for example, in the framework construction of aircraft. Duralumin was first made in Germany and developed by A. Wilm and associates, during the years intervening between 1903-1914. Duralumin is non-magnetic, withstands atmospheric influences, and offers unusual resistance to sea and fresh waters. It is only slightly affected by numerous chemicals which readily corrode other metals and alloys and does not tarnish in the presence of sulphurated hydrogen. It takes a polish equal to that of nickel-plated articles and remains bright without cleaning longer than plated or silvered articles. It is an ideal substitute for aluminum, German silver, brass, copper.

and steel when lightness combined with strength is required. Although duralumin is only one-third the weight of steel, heat-treated duralumin forgings approximate mild steel forgings in strength, so that wherever weight is a deciding factor, duralumin is satisfactory for most shapes made by hot-working or forging. Duralumin forgings are especially desirable for reciprocating or moving parts where the inertia due to their own weight, forms a large part of the total stress. Duralumin machines easily and, as it does not corrode, is suitable for use in many places where weight is not the prime essential.

Experiments have been made to determine the electrolytic effect from junctions of duralumin with iron or steel. These were made by riveting duralumin bars to iron plates and then placing them in artificial sea-water. The result was only a slight destruction of the iron and a reduction in the weight of the bars of about 0.23 per cent, so there is no objection to using duralumin and iron junctions in aircraft.

Duralumin Composition and Strength. The chemical composition of duralumin varies within the following limits: Copper 3 to 5 per cent, magnesium 0.3 to 0.6 per cent, manganese 0.4 to 1 per cent, the remainder being aluminum plus impurities. Small quantities of other metals are sometimes added for certain reasons; for instance, chromium may be added to increase the burnishing qualities of the metal. The strength and toughness of duralumin are comparable with mild steel, and are obtained with a specific gravity of about 2.8 as against 7.8 for steel. The melting point is approximately 1210 degrees F., the recalescence point, 970 degrees F., the annealing temperature approximately 680 degrees F., and the coefficient of expansion 0.00001798 per F. degree of temperature. In the annealed form duralumin can be drawn, spun, stamped, and formed into a great variety of shapes, similar to brass and mild steel. The physical properties in this state average: Ultimate tensile strength, 25,000 to 35,000 pounds per square inch; yield point, 22,000 to 24,000 pounds per square inch; elongation in 2 inches, 12 to 15 per cent; Brinell hardness, 57; and scleroscope hardness, 11.

Duralumin in its heat-treated form may be slightly shaped or formed and may be bent cold to 180 degrees over a mandrel having a diameter of four times the thickness of the sheet. Its remarkable tensile strength is here combined with its maximum elongation as follows: Ultimate tensile strength, 55,000 to 62,000 pounds per square inch; yield point, 30,000 to 36,000 pounds per square inch; elongation in 2 inches, 18 to 25 per cent; Brinell hardness, 93 to 100; and scleroscope hardness, 23 to 27. Heat-treated duralumin forgings have similar physical properties. When the sections of forgings are heavy, it is advisable to lower

the minimum tensile requirements to 50,000 pounds per square inch. This will cause a proportional increase in elongation. Heat-treated and hard-rolled duralumin is used where no bending or forming is required. It is a hard, strong, springy metal in this state, and machines and polishes well. Its physical properties in this form average: Ultimate tensile strength, 67,000 to 72,000 pounds per square inch; yield point, 58,000 to 65,000 pounds per square inch; elongation in 2 inches, 3 to 8 per cent; Brinell hardness, 130 to 140; and scleroscope hardness, 39 to 42.

Influence of Heat and Cold: Heat has an important influence on the strength of duralumin, the results of tests indicating that the strength decreases 10 per cent for an increase in temperature of 212 degrees F. and about 20 per cent for an increase of 302 degrees F. The loss in strength increases with the increase of temperature. On first heating the increase in elongation is hardly appreciable, and between 302 and 392 degrees F., it decreases. At 482 degrees F., the elongation becomes the same as at the room temperature. Upon further heating the elongation increases with a rising temperature; consequently, wherever duralumin is exposed to heat, the possible decrease of strength must always be considered. Opposed to this, the influence of cooling on the strength properties is less unfavorable. The strength and elongation increase somewhat with a decrease in temperature.

Duralumin Drop-Forging. Duralumin may be drop-forged in the same dies used for steel. Although the coefficient of expansion of aluminum is twice that of steel, the forging temperature is only one-half, so that dies with a shrinkage allowance for steel are suitable for duralumin. Best results are obtained by modifying the design of the drop-forging to suit duralumin, bearing in mind that duralumin does not flow quite so readily as steel. Owing to the sluggish flow, the dies must also be very smooth. The correct forging temperature is about 900 degrees F. If heated above 930 degrees F., duralumin becomes crumbly, and when drop-forged is likely to disintegrate. The correct forging temperature range, therefore, is important, but may vary from 880 to 920 degrees F.

Duralumin Gears. For a given section, the weight of duralumin is about one-third that of bronze, and for parts produced in large quantities, duralumin is the cheaper of the two metals. Therefore duralumin is an ideal material for worm-wheels, and especially those used in automobile constructions, provided the wearing qualities are satisfactory. The tensile strength and relatively high elastic limit insure a superior tooth strength, while the homogeneous structure and uniform hardness of heat-treated duralumin forgings insure entire freedom from hard spots, porosity and spongy areas so common in bronze castings, which

entail not only a machine loss but uneven tooth wear in service. The data from various laboratory tests on bronze and duralumin worm-wheels may be summarized by saying that tests destructive to duralumin worm-wheels were also destructive to those made of bronze.

An important condition was revealed in tests with worm-wheels made of duralumin, by examining the lubricant used. After long tests with bronze wheels where the oil has not been changed, the oil is found to contain particles of bronze in suspension. This condition is sometimes very marked and is of importance not only as indicating tooth wear but as showing the deterioration of the lubricating value of the oil. Oil heavily charged with metallic particles acts more like an abrasive and less like a lubricant, and therefore is an important factor in the wear of automobile gearing, where the oil is infrequently renewed. When duralumin wheels were used, the charging of the oil with metallic particles was practically negligible.

The different tests point to excellent life for duralumin worm-wheels, unless the wheels are roughened by lack of lubrication or too high a tooth pressure which will injure or destroy any worm-gearing. The same qualities that make duralumin a desirable material for worm-wheels also make this material valuable for other types of gears. It is suitable for this class of work when the pressures are sufficiently within its elastic limit of 30,000 pounds. Where this condition is met, and weight and quietness are desirable, duralumin will satisfactorily replace iron, steel, brass, fiber, fabrics, etc. Where duralumin can be run with steel rather than against itself the best results are obtained. An example of this application is found in the timing gear trains of automobile motors where both long life and quietness are essential. Helical duralumin gears alternated with steel gears have been very successful in service. That duralumin gears when meshed with steel gears are quiet may seem somewhat contradictory since, when struck, all duralumin forgings are resonant; however, quiet operation is obtained and is undoubtedly due to the difference in pitch of the sound vibrations of steel and duralumin.

When duralumin and hardened steel are run together the results are always good. An example of this application was shown by having duralumin connecting-rods running direct on the wrist-pins. A better life was obtained at this point than with bronze-bushed rods of equal bearing area. Comparative tests of bearings made from duralumin and bearings made from babbitt show that for shaft speeds exceeding 700 revolutions per minute and loads over 200 pounds per square inch, duralumin bearings developed less friction, remained cooler and showed practically no

loss in weight under most severe conditions. For lower bearing pressure and slower speeds, babbitt metal was superior.

Duralumin Heat-Treatment. An unusual feature of duraluminum is that after it has been hot-, or hot- and cold-worked, it may be further strengthened and toughened from 40 to 50 per cent by heat-treatment. This heat-treatment is somewhat analogous to the heat-treating of alloy steels and consists of quenching at temperatures below the melting point, followed by an aging process. The increased physical properties are not all produced immediately on quenching, but increase during the subsequent aging.

The final rolling or forging of duralumin may be done hot or cold, according to the character of the work being handled or the shape it is desired to produce. The hot- or cold-worked metal in its final shape shows greatly improved physical properties over the cast ingot, but the full development of its qualities is obtained only by a specific heat-treatment. To obtain this heat-treatment, the metal is heated to a temperature of from 930 to 970 degrees F. for a period of time depending upon the section of the piece, and then immediately quenched. The heating and quenching improve the physical qualities of the metal, but the maximum results are obtained only by a subsequent aging. During the aging period, which takes from one to five days, the tensile strength, hardness, and elongation of the alloy increase considerably. Aging is sometimes accelerated by placing the metal in a hot water bath of a temperature up to 212 degrees F. or in a hot room. The heat-treatment develops properties which have not been obtained in a like degree in any other aluminum alloy. The cast ingot has a tensile strength of from 28,000 to 32,000 pounds per square inch, and an elongation of from 1 to 3 per cent.

When duralumin in its finished state must be subjected to several drawing, forming, or similar operations, it is often found necessary to anneal the sheets between operations in precisely the same manner as with other metals. This annealing should be done at about 660 degrees F. If several drawing operations are to be performed, it may be necessary to anneal the metal between such operations. Annealed duralumin can be heat-treated and the maximum physical properties obtained, no matter what shape or form the metal may be reduced to; conversely, heat-treated duralumin may be annealed. Duralumin may be cold-worked after heat-treatment and aging. This operation produces a hard smooth finish, and materially increases the tensile strength of the metal at the expense of elongation.

Heat-treatment Experiments: In order to ascertain the relation between the heat-treatment of duralumin and its mechanical

properties, the Bureau of Standards made a series of experiments resulting in the following conclusions: When duralumin is rapidly cooled by quenching from temperatures between 250 and 520° C. (482 and 968° F.), and aged thereupon at temperatures from 0 to 200° C. (0 to 392° F.), the hardness and, at least at lower aging temperatures, the ductility increase. The actual values of hardness and ductility thus obtained depend upon the quenching temperature; they increase with that temperature up to about 520° C. (968° F.). In order to develop the best mechanical properties by heat treatment, a quenching temperature should be used as near this as is possible without running risk of burning the metal. In practice it should be possible to quench from temperatures between 510 and 515° C. (950 and 959° F.).

The period of time at which sheet material should profitably be held at the quenching temperature lies between 10 and 20 minutes. Heavier sections such as bars might require more time at this temperature, as the structure of such sections would be coarser. Quenching is best and most conveniently carried out in boiling water. The mechanical properties are better after quenching in hot than after quenching in cold water, and there is less danger of cracking due to cooling stresses.

The best temperature for subsequent aging depends upon the mechanical properties that are desired. For most purposes it will be found best to age at 100° C. (212° F.) for about 5 to 6 days. The greater portion of the hardening effect takes place within this period. Such a treatment develops both high strength and high ductility. If a material having a higher proportional limit but lower ductility is desired, the material may be aged at higher temperatures up to 150° C. (302° F.) for from 2 to 4 days.

Durimet. A nickel-chromium-molybdenum low-carbon steel having corrosion-resisting properties for the handling of corrosive liquids. Used for all parts that come in contact with such corrosive liquids as weak sulphuric and other acids, chlorine bleach solutions, and caustics.

Duriron. Duriron is a hard, white iron silicide, highly resistant to practically all commercial acids. The composition is approximately as follows: Silicon, 14.25 to 14.50; Carbon, 0.60 to 0.80; Manganese, 0.30 to 0.35; Sulphur, under .05; Phosphorus, under .15.

The hardness of duriron is such that it cannot be machined by a cutting tool and must be finished by grinding. Duriron can be used safely in connection with nitric, sulphuric, acetic, and a large list of other commercial acids at practically any concentration or temperature. This is also practically true of cold hydrochloric acid. With hot hydrochloric acid, however, more consideration must be given to the conditions.

Duronze. An alloy of high resistance to wear and corrosion, composed of aluminum, copper, and silicon, with a tensile strength of 90,000 pounds per square inch. Developed for the manufacture of valve bushings for valves that must operate satisfactorily at high pressures and high temperatures without lubrication.

Dust Separators. The function of the dust separator in an exhaust system is to clean the air returned to the atmosphere to the degree of cleanliness which will fulfill the purpose for which the system is installed. Thus, in a system designed to recover valuable wastes, the justifiable thoroughness of cleaning is regulated by the balance between the value of the material collected and the cost of recovery. When abatement of neighborhood nuisance is the principal purpose of a dust collecting system, the air cleaner must remove all or nearly all of the dust particles visible to the naked eye which would otherwise reach the zone of complaint. If the purpose of the system is to eliminate a health hazard, the separator must clean to a degree which will avoid dangerous recontamination of breathing zone air.

Dutch Metal. An alloy of copper and zinc resembling gold. It contains about 80 per cent of copper and 20 per cent of zinc.

Dutch Oven Furnace. The Dutch oven type of boiler furnace is especially adapted for the burning of bituminous coal. The furnace proper is extended in front of the boiler, and at the rear of this is a mixing wall or baffle which gives a hot wall for the burning gases to strike against as they rise from the bed of fuel. This gives the hydro-carbons ample opportunity, after being distilled from the fresh fuel on the grate, to become thoroughly mixed with the air before passing into the combustion chamber at the rear of the wall.

Dynamic Balance. When a rotating part is in dynamic or running balance, the effect of centrifugal force on any unbalanced masses has been counteracted sufficiently to meet practical requirements. Dynamic balancing is especially important for rapidly rotating parts, particularly when the length is great in proportion to the diameter so that unbalanced masses may lie in widely separated planes and thus cause excessive vibration. See Balancing.

Dynamic Brake. This is an electric brake used for slowing down and stopping motors driving industrial machinery, especially hoists and cranes. The motor acts as a generator, the generating action causing the motor shaft to absorb mechanical energy from the machine to which it is connected and thereby establish a braking action. Dynamic brakes are generally sup-

plemented by mechanical friction brakes, because the dynamic braking action ceases when the motor comes to rest.

"Dynamic braking" is the term used when power is absorbed in a rheostat, to distinguish it from "regenerative braking" which indicates that the power is returned to the constant voltage power system. A combination of dynamic braking and regenerative braking is used on crane hoists, elevators, reversing planers, etc. Sometimes regenerative braking alone is used on long hoists where the time of lowering is something like one-half of a minute or more. On electric trains traversing steep or long grades the use of regenerative braking results in considerable saving in power and wear on brake shoes and wheels. See Regenerative Braking.

Dynamic Electricity. The term *dynamic electricity* relates to electricity which flows through some kind of a conductor as a current; for example, when the terminals of one or more electrical batteries are connected by means of a wire, a current will flow through the wire from one terminal to another.

Dynamic Pressure. The pressure exerted by a fluid or gas, flowing in a duct or pipe, due to the momentum of the moving fluid in the direction of the flow.

Dynamite. Dynamite is nitroglycerine to which an absorbent has been added in sufficient quantity to form a solid mass, such as diatomaceous earth, clay, ashes, or carbon. It is important that the adulterant have the correct absorbing qualities, for an excess of nitro will naturally exude, while if the absorbent is in excess, it is likely to crumble. Either condition is likely to give serious trouble at some unexpected moment. Both nitroglycerine and dynamite are particularly dangerous, owing to their instability.

Dynamo. The name dynamo is an abbreviation of the longer original name, "dynamo-electric machine," and it is a machine for converting mechanical into electrical energy. The name "dynamo" is not used in the electrical industries today to the extent that it was used in the earlier days of the development of electrical machinery, the name *generator* having, in the United States at least, almost entirely replaced *dynamo.*

Dynamo Invention. The principle of the dynamo was discovered by Faraday in 1831 and demonstrated by him in a simple model consisting of a permanent horseshoe magnet and a copper disk which rotated between the magnet poles. Two circuit contacts were provided, one on the periphery of the disk and one on the spindle. The first dynamo-electric machine which utilized current from the armature, in the coils of the field magnets, was

invented by Hjorth of Copenhagen, and was patented in England in 1855. Although the principle of the dynamo was embodied in this patent, the practical value of such a machine was not appreciated until some time later, and the development of the highly efficient machine now in use has been due to the work of a number of different inventors. Patents for the polyphase or multiphase current type were granted to Tesla in 1888.

Dynamometers. A dynamometer is an apparatus for measuring the power developed, absorbed, or transmitted by any piece of machinery. *Absorption dynamometers* absorb the power generated or transmitted by any mechanism, measuring it during the process of absorption. Dynamometers of another type measure the power by transmitting it through the mechanism of the dynamometer from the apparatus in which it is generated, or to the apparatus in which it is to be utilized. Dynamometers of this class are known as *transmission dynamometers.* Dynamometers known as *indicators* operate by simultaneously measuring the pressure and volume of a confined fluid. Indicators are very seldom used, however, except for the measurement of the power generated by steam or gas engines or absorbed by refrigerating machinery, air compressors, or pumps.

Dynamometers of Electrical Type. An electrical dynamometer is an apparatus for measuring the power of an electric current, based on the mutual action of currents flowing in two coils. It consists principally of one fixed and one movable coil, which, in the normal position, are at right angles to each other. Both coils are connected in series, and, when a current traverses the coils, the fields produced are at right angles; hence, the coils tend to take up a parallel position. The movable coil with an attached pointer will be deflected, the deflection measuring directly the electric current.

Dynamotor. A dynamotor is a direct-current machine which combines both motor and generator action in one magnetic field; it is used for transforming high-voltage direct current into low-voltage direct current, or *vice versa;* hence, it performs the same functions with relation to direct current as a transformer does in relation to alternating current. These machines are used mainly for obtaining large currents for starting other motors, or for giving low voltages or a fractional voltage in a multi-voltage system, for speed control. They are also employed for obtaining a low voltage for telephone and telegraph systems, and for obtaining the low voltage and large currents required for electrolytic work. The dynamotor has an armature with two separate windings and two separate commutators. Either winding may be used as a motor winding and the other as a generator

winding. A dynamotor is smaller, lighter, and cheaper than a motor-generator set, although the latter has the advantages that the high- and low-voltage circuits are absolutely independent, and that there is no fixed relation between the two voltage values.

Dynapak Process. This high-energy-rate forming process makes use of high-pressure nitrogen gas. The machines used, which employ compressed nitrogen under a pressure of 2000 psi as the energizing medium, have an actuator which is a self-triggering gas-powered ram, capable of delivering the energy potential of the high-pressure gas instantaneously to a free piston-column assembly. The horizontally acting piston may be used either as a free impact tool to apply load to a workpiece, or it may be used as a sustaining thrust device to produce force at velocities at up to 400 feet per second. Velocity can be maintained within plus or minus one half foot per second.

The machines can be used for extruding, forging, sheet metal forming, compacting of ceramics and powdered metals, shearing and blanking. Three standard size machines are available. The smallest has a six-inch diameter bore, a twelve-inch piston stroke, and a work-platen ten inches in diameter. It is capable of producing 40,000 foot pounds of energy at velocities of more than 200 feet per second. The next larger standard machine has a twelve-inch diameter bore, a twelve-inch piston stroke, and work-platen 20 inches in diameter. This machine develops 160,000 foot-pounds of energy. The largest standard machine has an eighteen-inch diameter bore, a twelve-inch piston stroke, and work-platen 36 inches in diameter. It is capable of delivering 360,000 foot-pounds.

Dyne. One dyne is the unit of force in the C. G. S. (centimeter-gram-second) system, frequently also known as the *absolute system of measurement.* One dyne is equivalent to 1/981 gram, this value being derived from the fact that the acceleration due to gravity (at Paris) equals 981 centimeters in one second.

E

Earth Circuit. In electricity, an earth circuit is one in which the earth or ground forms the path for the current. Often a metallic circuit is grounded, as, for example, the return circuit for direct-current railways, where the track rails form the grounded return circuit. The negative terminal of the generator should always be connected to the grounded circuit, so as to minimize electrolysis.

Earth Load Capacity. See under Foundations for Machinery.

Earth or Soil Weight. Loose earth has a weight of approximately 75 pounds per cubic foot and rammed earth, 100 pounds per cubic foot. The solid crust of the earth, according to an estimate, is composed approximately of the following elements: Oxygen, 44.0 to 48.7 per cent; silicon, 22.8 to 36.2 per cent; aluminum, 6.1 to 9.9 per cent; iron, 2.4 to 9.9 per cent; calcium, 0.9 to 6.6 per cent; magnesium, 0.1 to 2.7 per cent; sodium, 2.4 to 2.5 per cent; potassium, 1.7 to 3.1 per cent.

Ebonized Monel. Monel metal with an ebony finish obtained through an oxidizing operation. The metal is identical with regular Monel except for the lustrous blue-black finish. It is immune to rust and resists discoloration at relatively high temperatures. Suitable for applications where appearance must be maintained at temperatures up to 1400 degrees F., as in reflectors, deflectors, element pans, etc., of electric heating units.

Eccentric. An eccentric is, in reality, a short crank with a crankpin of such size that it surrounds the shaft. The slide valve of many steam engines is driven by an eccentric attached to the main shaft. The *throw* of an eccentric is equal to the diameter of a circle described by the center of the eccentric as it rotates with the shaft. The travel of the valve equals the throw of the eccentric, unless there is an intervening rocker with lever arms of unequal length; which causes a variation in the movement of the valve. The radius of an eccentric, or the distance from the center of its shaft hole to the center of the eccentric, is sometimes referred to as the *eccentricity.* This radius is sometimes called the throw, although that is generally considered to be an incorrect definition.

Eccentric Gears. In some of the developments in automobile accessories, such as self-starters and speedometers, conditions

exist which require a high velocity ratio in a comparatively small space; this requirement has led to the development of what are commonly known as *eccentric gear combinations.* These combinations are, in reality, planetary gearing consisting either of two gears or of four or more gears.

Echols Thread. Chip room is of great importance in machine taps and tapper taps where the cutting speed is high and always in one direction. The tap as well as the nut to be threaded is liable to be injured, if ample space for the chips to pass away from the cutting edges is not provided. A method of decreasing the number of cutting edges, as well as increasing the amount of chip room, is embodied in the "Echols thread," where every alternate tooth is removed. If a tap has an even number of flutes, the removal of every other tooth in the lands will be equivalent to the removal of the teeth of a continuous thread. It is, therefore, necessary that taps provided with this thread be made with an odd number of lands, so that removing the tooth in alternate lands may result in removing every other tooth in each individual land. Machine taps are often provided with the Echols thread.

Economizer. An apparatus designed to save waste flue-gas heat in power plants is called an *economizer* and consists of a bank of tubes through which the water passes on its way to the boiler. The economizer is usually placed behind a row of boilers and a little above them. Although this heat is commonly used in warming the feed water, the term *feed-water heater* is only applied to devices employing either live or exhaust steam.

Eddy - Currents. Eddy - currents, sometimes also called "Foucault" currents, are irregular electric currents induced in an iron core or other metallic mass along closed paths of least resistance linked with the flux, when the magnetic flux varies in the core. These currents permeate the whole bulk of the core, with a resultant loss of energy in the form of heat. They may be considerably minimized by laminating the core.

Edison Battery. This is an alkaline storage battery in which the active material of the positive plate is nickel hydrate, the active material of the negative place is black oxide of iron, and the electrolyte is a solution of potash in water. It is widely used for railway signal systems, electric industrial trucks and tractors, police and fire alarm systems, emergency lighting and other applications where dependability and long service life are important factors.

Edison-Lalande Cell. This is a primary cell or battery in which the anode is amalgamated zinc in the form of two sheets hung at each side of the cathode. The depolarizer consists of

cupric oxide in the form of a plate, the surface of which is reduced to metallic copper to form the cathode. The electrolyte is a solution of potassium hydroxide or sodium hydroxide. The cell is used for closed circuits and large currents. The electromotive force is low—about 0.7 volt—but as the internal resistance is also low, the currents are large. The cell may be left unused for several months without evaporation, the electrolyte being covered with a layer of heavy mineral oil for this purpose.

Edison Wire Gage. The Edison wire gage is simply another name given to the circular mil gage system for measuring electric wires. The gage numbers correspond to the numbers of thousands of circular mils of area of cross-section of the wire; hence, a wire, the cross-section of which is 110,000 circular mils, is gage No. 110. The American or Brown & Sharpe wire gage is generally used for electrical wires, and may be considered the standard for this purpose.

Effective Pressure. The effective pressure in the cylinder of a steam engine varies throughout the stroke. The mean effective pressure (M.E.P.) is the average of all the effective pressures, and this average multiplied by the length of stroke gives the work done per stroke. The mean effective pressure may be determined from an indicator card, and it is used in calculating the *indicated horsepower* of an engine.

Effective Pull. The effective pull of a belt is the difference in tension between the tight and slack sides of the belt. The approximate horsepower that may be transmitted by a belt can be determined by multiplying the effective pull in pounds per inch of belt width, by the width of the belt in inches and the speed of the belt in feet per minute, and dividing the product thus obtained by 33,000. The allowable effective pull depends not only upon the kind and quality of the belt, but also upon the operating speed; for example, the effective pull per inch of width for a single-ply belt 3/16 inch thick and of good quality, may be about 65 pounds for a belt speed of 3000 feet per minute, whereas 50 to 55 pounds should not be exceeded for a speed of about 5000 feet per minute.

Efficiency of Mechanism. The efficiency of a machine is the ratio of the power delivered by the machine to the power received by it. For example, the efficiency of an electric motor is the ratio between the power delivered by the motor to the machinery which it drives, and the power it receives from the generator. Assume, for example, that a motor receives 50 kilowatts from the generator, but that the output of the motor is only 47 kilowatts. Then, the efficiency of the motor is $47 \div 50 = 94$ per cent. The efficiency of a machine tool is the ratio of the power consumed at the

cutting tool to the power delivered by the driving belt. The efficiency of gearing is the ratio between the power obtained from the driven shaft to the power used by the driving shaft. Generally speaking, the efficiency of any machine or mechanism is the ratio of the "output" of power to the "input." The percentage of power representing the difference between the "input" and "output," has been dissipated through frictional and other mechanical losses.

Mechanical Efficiency: If E represents the energy which a machine transforms into useful work or delivers at the driven end; L equals the energy lost through friction or dissipated in other ways; then

$$\text{Mechanical Efficiency} = \frac{E}{E + L}.$$

In this case the total energy $E + L$ is assumed to be the amount that is transformed into useful and useless work. The actual total amount of energy, however, may be considerably larger than the amount represented by $E + L$. For example, in a steam engine there are heat losses due to radiation and steam condensation, and considerable heat energy supplied to an internal combustion engine is dissipated either through the cooling water or direct to the atmosphere. In other classes of mechanical and electrical machinery the total energy is much larger than that represented by the amount transformed into useful and useless work.

Absolute Efficiency: If E_1 equals the full amount of energy or the true total, then

$$\text{Absolute Efficiency} = \frac{E}{E_1}.$$

It is evident that absolute efficiency of a prime mover, such as a steam or gas engine, will be much lower than the mechanical efficiency. Ordinarily, the term efficiency as applied to engines and other classes of machinery, means the mechanical efficiency. The brake horsepower of a steam engine or energy delivered to the fly-wheel, divided by the indicated horsepower or work done in the steam cylinder (as shown by an indicator card) equals the mechanical efficiency. This efficiency should be determined at full load. In the case of manufacturing machinery the energy available at the driven or working end divided by the energy supplied to the initial driving shaft equals the mechanical efficiency.

Efficiencies of Different Mechanisms: The efficiency of a given machine or machine element sometimes varies over a fairly wide range. Such variations may be due to different operating conditions, to differences in workmanship, or to variations in the design of a machine or machine element of the same general class;

hence, the specific figures which follow are merely intended to serve as a general guide and indicate, as far as possible, efficiencies under average conditions. The efficiencies of ordinary or plain bearings usually vary from 95 to 98 per cent. Roller bearings and ball bearings have efficiencies of about 98 to 99 per cent.

Spur gears with cut teeth and with bearings included have an efficiency of about 96 per cent, whereas bevel gears may have about 1 per cent less, or 95 per cent. Belt drive efficiencies range from 96 to 98 per cent; roller chain drives, from 95 to 97 per cent; and high-class silent chain transmissions, from 97 to 99 per cent.

Egg Coal. Coal in pieces of such size that they will not pass a screen of 2-inch mesh, but will pass a screen of 2¾-inch mesh.

Ehrhardt Process. This is a process of producing seamless tubing in which a piercing bar is forced into a solid billet, the cross-section of which corresponds to the area of the tubing to be made. This billet, heated to a white heat, is placed in a form which corresponds to the outer shape of the tube. The difference between the area of this form and the area of the billet must equal the area of the pierced bar. The metal forced from the center flows to the outside, occupying the space between the original billet and the form, which is equal to the amount of material displaced by the piercing bar.

Ejector Condenser. The ejector type of condenser is so constructed that the exhaust steam from the engine is condensed by mixing it directly with the condensing water. See Condenser.

Ekko Process for Making Molds and Dies. The "Ekko" process is a method of making molds and dies which has grown out of the research conducted by the United States Rubber Co. The process produces the molds and dies by what has been termed "electroforming" of iron against a pattern that is to be reproduced. Electroforming is simply a type of electroplating, except that deposits up to ½ inch thick can be made instead of 0.001 or 0.002 inch as in the usual electroplating processes. Electroplating is mainly used for decorative purposes or to provide corrosion resistance, while electroforming is used to build up an appreciable mass of metal.

When the heavy electroformed deposits of iron are separated from the underlying pattern, a cavity or die is obtained in which are reproduced the shape and surface finish of the pattern in every detail. This cavity or die, when properly "backed up" or mounted, can be used to mold or stamp objects of the exact shape of the original pattern.

After a mold has been produced by engraving, it can be reproduced as many times as desired by electroforming. The engraved mold is used to mold the pattern, which is later covered with iron by electrodeposition. In the case of tire patterns, the pattern on which the iron is deposited is made of rubber. The pattern is rendered conductive by dusting it with powdered graphite and polishing it vigorously with a light brush. The polishing operation adds to the finish obtained on the electroformed cavity. Patterns on which the iron is deposited may be of wood, glass, or plastics, provided the surface is made conductive to the current, as explained. Metal patterns are also satisfactory, with the exception of those made from zinc or aluminum, which are attacked by the plating bath.

The iron deposited by the process is 99.98 per cent pure, and practically free from porosity. It is about 50 per cent harder than cold-rolled steel; it has a scleroscope reading of 37, and a Brinell reading of 240. The deposited metal can be softened to the normal value for pure iron by annealing. It can also be hardened by carburizing; so that it will scratch glass. Electrolytic iron has a heat conductivity nearly twice that of cast iron or steel. This is of especial advantage in molding operations, where a high rate of heat transfer is desirable.

Elastic Bonding Process. See Bonding Processes for Grinding Wheels.

Elastic Cements. The various cements containing rubber are elastic, if the rubber is in a predominating amount; many containing boiled linseed oil, and the hectograph composition are quite elastic. The rubber and linseed-oil cement, given in the paragraph headed Acid-proof Cements, is very tough and useful for nearly all purposes except when oil vapors are to be confined. The most useful single rubber lute is probably the so-called Hart's india-rubber cement. Equal parts of raw linseed oil and pure masticated rubber are digested together by heating, and this mixture is made into a stiff putty with fine "paper stock" asbestos. It is more convenient, however, to dissolve the rubber first in carbon disulphide, and, after mixing the oil with it, to let the solvent evaporate spontaneously.

Elastic Grinding Wheels. Very narrow grinding wheels are made by the elastic process. Shellac is the principal ingredient in the bond, and the wheels made by this process are strong and have considerable elasticity, so that very thin wheels can be used safely. Wheels 1/32 inch thick are manufactured. Thin elastic wheels are used for slotting and for cutting off stock such as tubing, pipes, wire, thin sheets of tin or brass, and other materials, especially when the parts are difficult to hold for cutting

with regular tools. Thicker elastic wheels are employed for saw-gumming, grinding the teeth of gears, sharpening wood-working tools, etc. They are also used for cutlery work and roll grinding, where a very smooth polished surface is desired.

Elastic Limit. When external forces act upon a material, they tend to produce stresses within it. All stresses to which a material is subjected cause a deformation. If the stress is not too great, however, the material will return to its original shape and dimensions when the external stress is removed. The property which enables a material to return to its original shape and dimensions is called *elasticity*. If a material has been stressed to such an extent that, upon the removal of the load, it does not fully return to its original shape and dimensions, its *elastic limit* has been exceeded. Up to the elastc limit, the deformation is directly proportional to the loads. When the elastic limit is exceeded, the extensions in a material under stress cease to be proportional to the loads. The elastic limit can only be determined by the skillful use of very delicate instruments and by the measurements of the extensions for small successive increments of load. It is impossible to determine the elastic limit in ordinary commercial testing. For this reason, the ultimate strength of materials is more commonly used in the calculation of strength than the elastic limit, although the value for the elastic limit is a more accurate measure of the stress-resisting properties of the material, and in all engineering designs, the load applied to the material must never be so great that the elastic limit is exceeded. The elastic limit should not be confused with the *yield point*, which is the point where the extension of a material under test increases without increase of load.

Elastomer. An elastomer may be either a natural or a synthetic rubber-like material, but the term is more likely to be used to describe a synthetic rubber-like material being employed in place of natural rubber.

Elbow. An elbow or "ell" is a fitting that makes an angle between adjacent pipes. The angle is always 90 degrees, unless another angle is specified. The name *branch elbow* is used to designate an elbow having a back outlet in line with one of the outlets of the "run." It is also called a "heel outlet elbow." A *double-branch elbow* is a fitting that, in a manner, looks like a tee, or as if two elbows had been shaved and then placed together. forming a shape something like the letter Y or a crotch. A *drop elbow* is a small-sized elbow that is frequently used where gas is put into a building. These fittings have wings cast on each side. The wings have small countersunk holes so that they may

be fastened by wood screws to a ceiling or wall or framing timbers. A *union elbow* has a male or female union at one end. A *service elbow* has an outside thread on one end and is also known as a "street elbow."

Electric Accumulator. The expression "electric accumulator," is seldom or never used in the United States to designate a battery for storing electrical energy, but this term is frequently so used in other English speaking countries. In the United States "storage battery" is the accepted expression.

Electrical Condenser. See Condenser, Electrical.

Electrical Conductors. See Conductor Materials.

Electrical Discharge. Discharge, in electricity, is the equalization of the potential difference between the terminals of a condenser or other source of electricity, on their connection by a conducting medium or as a result of the breakdown of the insulating medium between them. The term also applies to the removal of a charge from a conductor by connecting the same to the earth. *Brush discharge* is a faint luminous discharge which takes place from a positively charged pointed conductor.

Electrical Discharge Machining. In this process, a series of electrical discharges take place between the work and the tool or electrode which is formed to the desired shape of the hole. The rate of discharge may vary between 20,000 and several million per second. For each discharge, the voltage builds up between the electrode and the work and negative electrons pile up on the surface of the electrode. Eventually these electrons break through the surface barrier of the electrode and bombard the surface of the work. At each discharge, minute areas of the work surface become so hot that particles of the metal are vaporized and washed away by the coolant.

The tool can be of any shape, and can even be threaded to cut a thread in the work. In this case, of course, the tool must be rotated as it is fed down. The tool is usually made of free-machining brass, and is ground 0.001 inch smaller than the required hole size. The quality of finish on the work can be varied from rough to extremely fine by changing the settings on the machine.

The process can be applied to cutting the hardest metals, but perhaps its most useful field lies in correcting hardened steel dies and in drilling holes which were accidentally omitted before the work was hardened. It can also be used to make dies from hardened steel, thus avoiding the danger of the finished die cracking or distorting during the hardening process.

A variant of electrical-discharge machining is *electrical-discharge grinding*. A special machine is usually employed in this type of grinding, but any conventional grinder can be modified to use the process by substituting a brass wheel for the usual grinding wheel and adding a switch box and motor. The normal motor must be changed to a geared motor to reduce the wheel speed to about 100 revolutions per minute and insulation must be provided between the wheel and the work support.

The wheel does not actually touch the work so there is no danger of jamming and plunge cuts can be taken directly into the work. Automatic power feed maintains a constant gap between wheel and work, and because no heat is developed in the work, there is no danger of heat cracking. One particular advantage of this process in grinding carbide-tipped tools is that both the carbide tip and the steel shank can be ground at the same time, and rough and finish cuts can be taken without changing wheels.

Electrical Horsepower Equivalent. See under Horsepower.

Electrical Resistance Standards. Manganin, an alloy of copper, manganese, and nickel, is generally used as a resistance alloy for the wire-wound standards that maintain the unit of electrical resistance in our national standardizing laboratories. The United States Bureau of Standards, however, has found that an alloy consisting of 85 per cent copper, 9.5 per cent manganese, and 5.5 per cent aluminum is superior in several respects for this purpose. Alloys for the use mentioned must be very stable in resistance. When properly baked, coils of wire made from the new alloy show advantages over manganin.

Electrical Sheet Steel. Because of its particular adaptability for use as a core material in magnets, transformers, and motor and generator armatures, a special kind of steel in sheet form which contains from ¼ to 4½ per cent silicon, is designated as electrical sheet steel. It is used in a large number of different gages to form core laminations which serve to restrict eddy-currents. Sheets with high silicon content (within the above-stated range) have the lowest eddy-current and hysteretic losses, low saturation flux densities, and high permeability, but are somewhat stiff, lacking ductility. They are used for power transformers, distribution transformers, and high-efficiency motors and generators. Sheets with low silicon content, on the other hand, are quite ductile but have less desirable magnetic properties. Because high ductility is important from the standpoint of wear on dies in large quantity production and because some sacrifice in magnetic qualities can be made in the lower grades of motors, such as single-phase fractional-horsepower motors for

intermittent duty, this low-silicon steel is widely used. In between these two extremes, various grades are available to meet the requirements of many different kinds of cores.

Electric Arc. An electric arc is the luminous arc formed when a current of electricity passes from one conductor to another through a gas or vapor which has been brought to incandescence by the discharge of electricity. The conductor from which the current passes into the incandescent gas or vapor is known as the *positive electrode,* while the conductor to which the current passes is called the *negative electrode.* A common use of the electric arc in the industries is in electric arc welding.

Electric Currents. Electric currents have been classified by the Standards Committee of the American Institute of Electrical Engineers as follows: A *direct current* is a unidirectional current; as ordinarily used, the term designates a practically non-pulsating current. A *pulsating current* is a current that pulsates regularly in magnitude; as ordinarily employed, the term refers to a unidirectional current. A *continuous current* is a practically non-pulsating direct current. A *periodic current* is an oscillating current, the values of which recur for equal increments of time. An *alternating current* is a current that alternates regularly in direction; unless distinctly otherwise specified, the term "alternating current" refers to a periodic current with successive waves of the same shape and area. An *oscillating current* is a periodic current the frequency of which is determined by the constants of the circuit or circuits. Alternating current has the advantage over direct current in that simpler generating machines and generally more rugged motors may be used; but the chief advantage is that it is possible to obtain and use very much higher voltages than can easily be obtained or used with direct current. Alternating current is, therefore, used whenever distant transmission of electric power is necessary.

Electric Fixture Thread. The special straight electric fixture thread consists of a straight thread of the same pitches as the American standard pipe thread, and having the regular American or U. S. standard form; it is used for caps, etc. The male thread is smaller, and the female thread larger than those of the special straight-fixture pipe threads. The male thread assembles with a standard taper female thread, while the female thread assembles with a standard taper male thread. This thread is used when it is desired to have the joint "make up" on a shoulder. The gages used are straight-threaded limit gages.

Electric Furnaces. Electric furnaces may be divided into three general classes, according to the method by which the heat is generated: 1. Arc furnaces. 2. Induction furnaces. 3. Re-

sistance furnaces. With regard to the purpose of the furnaces, they may be divided into two large groups, melting furnaces, and heating furnaces. *Arc furnaces* produce heat by means of an electric arc between two electrodes, usually of carbon. The arc furnace may be considered as a resistance furnace in which the resistor is a gas. The resistance of gas at atmospheric pressure is greater than that of any solid resistor having the same dimensions as the arc, and, therefore, the amount of heat that can be produced in a given space is greater in an arc furnace than in any other type of furnace. Arc furnaces are used mainly for melting iron or steel. One type of *induction furnace* may be defined as a static transformer having a low tension "winding" formed by the material to be heated. Induction furnaces are, therefore, exclusively melting furnaces. Another type utilizes high frequency current which heats the material by means of eddy-currents.

Resistance furnaces may be divided into two types, those in which the current is conducted by the materials to be heated with or without electrolysis, and those in which the current is conducted by a special resistor. The charge or the resistor is connected directly to the source of the current supply. The heat developed in both induction and resistance furnaces is generated by the passage of a current through the resistance offered by the charge in the furnace or by the special resistor. Resistance furnaces are mainly used as heating furnaces, but are also employed for melting metals and alloys having a comparatively low melting point.

A special type of furnace which, perhaps, is the most useful of all for melting materials having a low fusing point is one which embodies the principles of both the arc and the resistance furnace, or the induction and resistance furnace. In this type of furnace, the current is started by means of an arc or by means of induction, and, when once a conductor has been established by the melting charge, the heat is maintained as in a resistance furnace.

Electricity. Electricity itself cannot be defined except in a very general way. It may be said to be a form of energy, the same as light and heat. However, electrical engineering deals with what can be *done* with electricity and not with what it is. In fact, what electricity *is* does not concern the electrical engineer any more than what gravity is concerns the mechanical engineer. Strictly speaking, the exact nature of electricity is not *definitely* known at the present time but the effects due to it and the laws that these effects follow have been very thoroughly investigated and determined. Thus it may be said that electricity is a physical agent pervading the atomic structure of matter and characterized by being separable, by the expenditure of energy,

into two components designated as positive and negative electricity, in which state the electricity possesses recoverable energy. The quantity of electricity on (or in) a body is the excess of one kind of electricity (positive or negative) over the other kind (positive or negative).

Electricity in the form of a charge or in the form of a current may be produced either by means of batteries—devices by which chemical energy is transformed into electrical energy—or by means of electric (electromagnetic) generators—rotating machines with conductors for electricity which move with relation to magnets in such a manner that an electric current is produced. Electricity may also be produced by so-called "thermo-couples," that is, by two dissimilar metals placed in proximity to each other and subjected to temperature differences, and by "static machines," in which the electricity is produced by the rubbing of two substances against each other. These two latter methods are of comparatively small commercial importance.

Electric Light Invention. Sir Humphrey Davey discovered in 1809 that the separation of the charcoal terminals of a powerful battery caused the formation of a brilliant electric arc, producing light that exceeded in intensity all the other known forms of light. This discovery led to the development of methods of feeding one carbon terminal toward another in order to maintain an arc, but for many years such arc lights were confined to the laboratory, since the current could only be obtained at that time from batteries. Very efficient electric lamps, however, used in conjunction with batteries, were devised by Foucault, Duboscq, Deleuil, and others, as early as 1853. The real development, however, of the electric light began with the invention of the dynamo. Among those who made notable contributions to arc light development should be mentioned Brush, Weston, Thomson, and Houston.

Although Thomas A. Edison is credited with the invention of the incandescent light by decision of the courts, as well as popular opinion, the first incandescent light is said to have been devised in 1840 by William R. Grove, inventor of the Grove battery. In 1845 an incandescent lamp was patented in England by August King, who acted as an agent for a Mr. Starr, an American inventor. This lamp was known as the Starr-King lamp. The Jablochkov electric light was first introduced in 1876 to light the streets of Paris. William E. Sawyer applied in 1877 for a United States patent for an electric engineering and lighting system. The form of incandescent electric lamp which resembles in its main features the modern type, was patented by Edison in 1880. This lamp had a thin filament of carbon which was sealed in a vacuum so that it would not burn away but remain incandescent. The small carbon filament and its high resistance

permitted proper distribution of current to a number of lamps without special regulation. Moreover, the cost of making lamps was low enough to permit discarding them when the filament was finally destroyed as the result of use. The claims of Mr. Edison were contested by William E. Sawyer and his partner Albon Man, which at first resulted in the grant of a patent to Sawyer and Man in 1885. This was followed, however, by patent litigation in the courts which terminated in 1892 in a decision by the United States Court of Appeals awarding the incandescent lamp to Edison.

Electric Railway Origin. The first electric railway was constructed in Berlin in 1879 by Dr. Werner Siemens. The first electric railway in the United States was constructed in 1885 and extended from Baltimore to Hampden, a distance of two miles.

Electric Riveter. See Riveter, Electric Type.

Electric Shock. An accidental electric shock usually does not kill at once, and may only stun the victim and stop his breathing temporarily. The victim of an electric shock can be restored only by prompt and continued use of artificial respiration. Break the circuit immediately. With a single quick motion separate the victim from the live conductor. In doing so, the person coming to the rescue must avoid receiving a shock himself by using a dry coat, a dry rope, a dry stick or board, or any other dry nonconductor, to move the victim or the wire so as to break the electrical contact. If the body of the victim must be touched by the hands, cover them with rubber gloves, a mackintosh, a rubber sheet, or thick, dry cloth. Also stand whenever possible on a dry board or some other dry insulating surface, and, if possible, use only one hand. If the victim is conducting the current to the ground and he is convulsively clutching the live conductor, it is easier to shut off the current by lifting him from the ground than by trying to break his grasp. Open the nearest switch, if that is the quickest way of breaking the circuit; if necessary, cut the live wire by using a hatchet or an axe with a dry wooden handle or properly insulated pliers. As soon as the patient is clear of the live conductor, begin artificial respiration at once. *Every moment of delay is dangerous.* Continual artificial respiration is necessary without interruption until breathing is restored; even after natural breathing begins, carefully watch that it continues. If it stops, start artificial respiration again. During the period of operation, keep the victim warm by applying proper covering and by laying bottles or rubber bags filled with warm (not hot) water beside his body. Do not give the patient any liquids whatever in the mouth until he is fully conscious.

Electric Soldering. The general method of electric soldering, as distinguished from soldering with an electric iron, consists of holding the pieces to be joined by clamping jaws with the ends of the work in firm contact; a heavy current of electricity, regulated to heat the joint sufficiently to melt the solder, is next passed through the work. The solder, in the form of tape or wire, is then applied to the joint. It flows in and around all parts heated to the proper temperature, as when using a gas flame, but the "life" or temper is retained in pieces that have been electrically soldered, instead of their being left in an annealed condition as when heated with a flame. Practically all the metals, such as brass, copper, steel, German silver, gold, and silver can be soldered successfully by means of the electric soldering process; this method is the most economical for a continuous run of work. The current used for electrical soldering should be a single-phase alternating current of any frequency between 40 and 60. A higher frequency could be used, but it is not good practice.

This method of joining metal pieces together resembles resistance welding in that an electric current is passed through the work to provide heat at the joint. It differs from it, as all soldering differs from welding, in that none of the metal to be joined is melted.

Electric Steel. Electric steel is so called because it is made in some type of electric furnace. The charge of raw material may be melted in the electric furnace, or the latter may be used for refining molten metal which has been partly refined in the open-hearth furnace. In some cases, the Bessemer converter is also used. The smaller electric furnaces melt cold charges, but some of the larger installations receive the metal in a molten condition. The electric furnace produces high-grade steels and it may be used for making special alloy steels, tool steel, steel castings, and for certain other metallurgical processes. Steel may be produced in the electric furnace that is chemically purer than steel made by any other process.

Electric Welding. In electric welding processes, the parts to be welded together are heated to a welding temperature by means of an electric current. There are two main systems of electric welding: (1) Electric resistance welding; (2) electric arc welding.

Thomson or Resistance Process: The Thomson or resistance process consists in forcing through the parts to be welded such a large volume of current that the resistance of the work is sufficient to cause fusion and welding of the metals. The parts to be welded are held between two clamping members of the welding machine, which form terminals for an electric current of low voltage and high amperage. When these clamps are forced together,

the work completes the circuit, and current is transmitted directly through it from one electrode to the other. With this method of welding, the interior of the metal is raised to a welding temperature before the surface reaches that heat, and the heat generation is so rapid that the loss is negligible. Resistance welding makes possible the uniting of forgings and stampings into integral, strong, light-weight parts at a speed unequalled by any other process. A motor car in which practically no castings are used, except in the power plant, can thus be produced.

Resistance Welding Methods: The following terms used in designating resistance welding methods, have been approved as an American Standard by the American Standards Association.

Butt Welding: A resistance welding process wherein a butt joint is employed.

Flash Welding: A resistance butt-welding process wherein the welding heat is developed by the passage of current in the form of an arc across a short gap between the surfaces to be welded, these surfaces being kept slightly separated until they have flashed off to parallelism and have reached the desired temperature. The electrical circuit is then opened and the upsetting movement takes place. The operation of the machine may be manual, semi-automatic, or fully automatic. The name "flash" arises from the fact that during the heating period oxidizing metal is thrown off in a shower of sparks.

Percussive Welding: A resistance welding process wherein electric energy is suddenly discharged across the contact area or areas to be welded and a hammer blow is applied simultaneously with or immediately following the electrical discharge.

Pressure Welding: A process of welding metals in either the highly plastic or fluid state by the aid of mechanical pressure. This process includes the resistance welding form of electric welding and the pressure type of thermit welding.

Resistance Welding: A pressure welding process wherein the welding heat is obtained by passing an electric current between the contact areas to be welded.

Seam Welding: A resistance welding process wherein the weld is made lineally between two contact rollers or a contact roller and a contact bar.

Spot Welding: A resistance welding process wherein the weld is made in one or more spots by the localization of the electric current between the contact points.

Application of Different Welding Methods: The extent to which different welding methods are used varies in different industries. The types of resistance welding most generally used in the automotive industry are spot-welding, flash butt-welding, upsetting, seam welding, and projection welding. To illustrate the relative

use of different methods, one type of car has 3240 resistance welds in the body and chassis, of which 44 are flash butt-welds, 2 are seam welds, and 3194 are spot-welds. In addition, there are a number of welds in the parts made by part manufacturers and by makers of accessories used on this car.

Arc Welding Process: When welding by the arc process one wire of an electric circuit is connected with the part to be welded and the other is attached to an electrode, so that the current passes across a short air gap between the work and the electrode, thus generating intense heat, the air being a poor conductor and offering a high resistance to the electricity. The heat of the arc is the hottest flame obtainable, the temperature varying between 3500 and 4000 degrees Centigrade (6332-7232 F.) according to estimates. By placing the electrode in contact with the metal and instantly withdrawing it a short distance, the arc is established. As the result of the heat thus produced, the metal may be entirely melted away or fused to another piece of metal, as desired. The electrode is the negative terminal and the metal to be welded is the positive terminal. Electric arc welding processes differ both in regard to the type of electrodes used and the kind of electric current.

Arc Welding Terms: Arc Welding—A fusion welding process wherein the welding heat is obtained from an electric arc formed either between the base metal and an electrode or between two electrodes with or without the use of gases.

Arc Welding Electrode: Filler metal in wire or rod form, or a carbon (or other suitable material) rod, used as one (or both) of the terminals in an electric circuit in order to produce a welding arc.

Bare Electrode: A metal electrode which is not fluxed or covered.

Base (Parent) Metal: The material that is welded (or cut).

Carbon Arc Cutting: A process of severing metals by melting with the heat of a carbon arc.

Carbon Arc Welding: An arc welding process wherein a hard carbon or graphite electrode is used, and filler metal, if required, is supplied by a welding rod.

Coated Electrode: A fluxed electrode having the flux applied externally by dipping, spraying, painting, or similar methods.

Composite Electrode: A fluxed electrode having one or more filler materials combined mechanically with the flux or covering.

Covered Electrode: A metal electrode having an external wrapping or braiding of paper, asbestos, or other material. A flux may be included with the covering.

Filler Metal: The material that is added to the base metal to

produce the weld in some forms of the fusion welding process. (See "Welding Rod" and "Arc Welding Electrode.")

Flux: Material used in welding to prevent the formation of oxides, nitrides, or other undesirable inclusions in the weld and to eliminate those that have formed. In metal arc welding, it is also employed to aid in the retention of the various elements of the electrode and to retard the rate of cooling of the weld metal.

Fluxed Electrode: A metal electrode provided with a flux.

Flux Encased Electrode: A fluxed electrode having the flux between a metal core and a sheath.

Shielded Carbon Arc Welding: A carbon arc welding process wherein the molten filler and weld metals are effectively protected from the air by supplemental means.

Shielded Metal Arc Welding: A metal arc-welding process wherein the molten filler and weld metals are effectively protected from the air by supplemental means.

Electrochemical Cleaning. Alkaline substances, such as sodium carbonate, potassium carbonate, potassium hydroxide, and sodium hydroxide in solution in varying degrees of concentration, and with small portions of potassium cyanide, develop sufficient hydrogen, with a current of from 4 to 8 volts, with the bath at nearly boiling temperature, to entirely remove all organic substances from the surface of metal, leaving it chemically clean. The action of an electro-cleanser is similar to the action of an electroplating bath. The only difference, as far as the development of gases is concerned, is that no metal being in solution and the anode being insoluble, no metal is deposited; but with a strong current a copious supply of oxyhydrogen gas is developed and attacks the organic matter upon the surfaces of articles to be cleaned, practically lifting off this matter and, by rapid evolution of the gases, carrying it to the surface. The small quantity of potassium cyanide contained in solution absorbs the slight oxidation that might be upon the surface, and by the combined action produces a surface clean enough, after washing in clear water, for any deposits.

The electrochemical cleaning solution should consist (for ordinary purposes) of from 3 to 4 ounces of caustic potash to each gallon of water, and to every 100 gallons of solution, 8 ounces of cyanide of potassium. This can be varied according to conditions. It is advisable to add at least ¼ pound of cyanide each week. Where the articles, such as iron or steel, contain much oil or grease upon the surface, the density of the solution can be increased. For articles of brass, copper, or bronze that have been polished, use a solution of carbonate of soda in the proportion of

2 ounces of soda and ½ ounce of caustic potash to each gallon of water, with the addition of 4 ounces of cyanide to every 100 gallons of solution.

Electrochemical Equivalent. The factor 0.001118 is called the *electrochemical equivalent* of silver; the electrochemical equivalent of other metals will be found in standard chemical and electrical handbooks. There is a simple relation between the electrochemical equivalent of various metals and their atomic weights and valences, which is as follows:

$$\text{Electrochemical equivalent} = \frac{\text{atomic weight}}{\text{valence} \times 96{,}494}$$

The atomic weight divided by the valence is known as the *chemical equivalent* and the factor 96,494 is known as the *faraday*. The weight, in grams, of a substance carried to an electrode by electrolytic action always equals the electrochemical equivalent of that substance multiplied by the number of coulombs passed through the cell.

Electrochroma. Electrochroma is a plating process for obtaining various colors on metals and alloys by electrolytic action. It is possible to produce various shades of green, blue, red, violet, yellow, or black by immersion of from one-half to two minutes in the electrolyte. The work is made the cathode.

Electrode. The poles or terminals of an electric battery are known as *electrodes*. The pole or terminal which is at the higher potential is called the *positive pole* or *terminal*, while the other pole is the *negative pole* or *terminal*. The positive pole is known as the *cathode* and is the negative electrode, while the negative pole or *anode* is the positive electrode. In a copper-zinc battery, for example, the copper is the positive pole, but the negative electrode or plate.

The elements of an arc lamp or furnace between which an electric arc is struck are termed electrodes.

The positive and negative elements in an electroplating bath are also so designated.

Electro-Deposition on Worn Parts. A simple process, developed at the Westinghouse Research Laboratory, for building up worn parts by the electro-deposition of iron, has been used for shafts, pins, bolts, gear centers and similar parts, and with very little modification can be employed to build up the worn surfaces inside automobile engine cylinders. Commercial salts are used and a current of sufficient density is employed to permit all ordinary repair work to be removed from the plating bath at the end of two or three hours. The cost of building up and

machining is kept low enough so that it will pay to reclaim a piece with this process rather than use a new one.

Cleaning: After thorough cleaning by any conventional means, it is essential, if adherent deposits are to be obtained, to give an anodic treatment in sulphuric acid, using sufficiently high current density to secure passivity. Westinghouse Research Laboratory used 30 per cent H_2CO_4 for about three minutes, at a current density of 3 to 5 amperes per square inch.

The Plating Bath: A plating bath made up in the following proportions has proved best: 2.5 pounds of commercial ferrous ammonium sulphate per gallon of city water plus a small amount of ferrous carbonate (freshly precipitated and kept under water in order to keep the solution practically neutral) plus a small amount of powdered charcoal, which helps to prevent pitting.

The Process: All small pieces are plated in earthenware crocks, and large pieces in lead-lined wooden tanks or stoneware tanks. Waterproof cement tanks can also be used. All contact of the solution with wood should be avoided as this always results in hard, brittle, specular deposits instead of the silvery, ductile ones obtained under proper conditions. The anodes are made of "Armco" iron, and are cylindrical in shape. Micarta disks with a hole cut in the center are fitted in each end of the anodes. The pieces to be plated are made the cathode and held stationary so that they extend into the plating solution through the holes in the micarta disks. The anodes are attached to a device which moves them up and down, thus keeping the plating solution stirred and the ferrous carbonate and charcoal in suspension. The temperature is held at approximately 60 degrees C., a few degrees variation either way not doing any harm. A current density of 0.43 ampere per square inch is used. This deposits metal at a rate that increases the diameter 0.006 inch per hour. This method of procedure applies only to pieces such as shafts, bolts, pins, etc.

Plating Inner Surfaces: For pieces such as gear centers, automobile cylinders, etc., where the inside diameter needs to be reduced, the anode is made to go down through the center, and micarta rings are fastened to the anode to obtain the required stirring. The current density could be raised considerably, but as the density specified adds the deposited material at the rate of 0.003 inch on a side or increases the diameter at the rate of 0.006 inch per hour, it is evident that the ordinary repair job requiring an increase in diameter of approximately 0.010 inch to 0.020 inch can be quickly completed. It is impossible to build up a piece accurately to size, and so it is necessary to build the work up a few thousandths over-size and then turn or grind it to the finish size. This method of recovery can be used with steel

or cast iron, and the deposited material can be case-hardened when necessary.

Electrodes, Welding. See under Electric Welding; also Elkonite Electrodes.

Electrodynamic Ammeter. See Ammeter.

Electrodynamic Wattmeter. See Wattmeter.

Electrodynamometer. The electrodynamometer is used in electrical laboratories for the measuring of electric current and power, especially in alternating-current practice. The instrument depends upon the action of one circuit carrying current upon another circuit carrying the same current. The working parts of the instrument consist simply of two coils, one fixed and the other movable, together with the required indicating means. Commercial instruments of this type for measuring currents are suitable for measurements as small as 0.02 ampere. When properly calibrated and used, the readings of a Siemens electrodynamometer may be relied upon to be accurate within 0.1 per cent, for a full-scale deflection. For smaller deflections, the accuracy is not quite so great.

Electro-Erosion. British terminology for Electrical Discharge Machining. See Electrical Discharge Machining.

Electro-Etching. Etching may be done by the use of electricity. When the wires leading from the poles of an electric battery are placed in a solution of copper sulphate, and a copper plate is attached to the positive wire, the object to be plated being attached to the negative, an electroplating outfit is formed. The deposition of a metal will not take place on any substance but a metallic one, and it is this fact which makes it possible to employ electricity in etching. When the battery is in action, the copper is taken from the anode, or article attached to the positive wire, and deposited on the cathode or article attached to the negative wire. First let it be assumed that a piece of sheet copper is used as a cathode. In the ordinary course of procedure, the copper from the anode, when properly regulated, will be removed and deposited in a fairly even surface on the cathode. Now suppose that a design is painted on the anode like the letter A with wax, varnish, or any substance that will not be affected by the solution. When the current is flowing, the copper will be removed only from the exposed surface of the anode; the protected surface will not be affected. In consequence, it will be found that after a time the design will stand out in relief. This illustrates the principle, but the method may be varied; for instance, the background may be coated instead of the design, in which case

the figure will be etched and the ground will stand out. Also, the operation may be performed on the cathode instead of on the anode, in which case the exposed parts are built up. The variations possible in using this process may be shown by the following example: Expose the letter A on an anode of copper or gold. The result will be that the letter will appear in relief. It should then be carefully rinsed in clean water without disturbing the ground. Suppose, for instance, that gold is used and it is exposed on the cathode in a silver bath, the silver being deposited in place of the gold that has been removed. Removing the piece from the bath and cleaning, the letter A is found designed in silver on a background of gold. This method is, of course, applicable to any combination of metals.

Electrolimit Gages. The electrolimit gage combines mechanical gaging with electrical magnification to obtain external and internal measurements. This gage uses a simple balanced bridge circuit, arranged so that any mechanical movement of the gaging points unbalances the magnetic field of the coils, the reading being shown on the micro-ammeter.

The electrolimit gage may be used either in the machine shop or in the inspection department. The degree of magnification is easily adjusted, magnifications of 20,000 to 1 being used where such accuracy is essential, as in the case of checking precision gage-blocks within a few millionths of an inch. The indicating instrument or micro-ammeter can be located at any convenient position.

The automotive industry has taken full advantage of new gaging equipment to facilitate manufacture and at the same time improve the quality of its product. With electrical gages properly designed for each operation, pistons and cylinder bores, as well as wrist-pins and other parts, are accurately graded for selective assembly. Better fits at lower costs, producing quieter and longer-lived engines, have resulted from the use of these modern gages.

Use of Electrolimit Gages in Rolling Sheet Metal: The extensive use of tin plate, strip, and sheet steel has called for increased accuracy and greater efficiency in rolling mill operation. These conditions are similar when materials other than steel are rolled in strip and sheet form. Three types of gages have been responsible for reducing the operating cost of producing strip steel by permitting higher speeds on the mills, with increased accuracy, greater efficiency in mill operation, and increased efficiency in inspection through the continuous classification of the sheared sheets.

The continuous electrolimit gage employs a combination of

mechanical gaging contact and electrical magnification. The gaging rolls control the electrical circuit in such a manner that errors in the material being checked are revealed in a greatly magnified and visible form on a micro-ammeter, which can be located at any desired point remote from the gaging unit. Electrolimit gages as applied to cold reduction mills permit accurate gaging of strip at speeds up to 1500 feet per minute. Some strip tin mills are holding their gage tolerance at ± 0.00025 inch at such speeds.

Sheet Classification: Another application of the continuous electrolimit gage is in the classification of sheets. In this operation, the gaging is done while the material is in the strip form, the sorting of the sheets being accomplished after the strip has been cut to the required lengths on the flying shear. The time relation between the gaging unit and the sorting mechanism can be accurately controlled, thus the gaging and sorting of sheets becomes a dependable operation, and the "off gage" sheets are positively separated from the approved sheets.

Strain Gage: Still another use of the electric gage is in the application of the strain gage for measuring the pressures exerted on rolling mills. Instruments capable of recording, as well as indicating, the loads on the mill have proved their practical value in the rolling of steel, paper, rubber, copper, and on other types of equipment, where it is desirable or necessary to know the exact pressures being exerted. In common with most mechanisms, rolling mills are designed to give maximum efficiency at a predetermined rolling pressure, and the strain gage permits reaching the efficient rolling pressure, as well as reducing the hazard of equipment failure caused by unintentional overloading. Briefly, the strain gage measures the stretch in the housing when pressure is applied, and converts this stretch of thousandths of an inch into pounds pressure. The result can be read on an indicating instrument remote from the mill.

Electrolon. The trade name "Electrolon" is used by the Abrasive Company for Silicon-carbide products. See Silicon Carbide.

Electrolysis. The corrosion of metal in the earth or in structures, due to the action of stray or leakage currents from conductors carrying electric energy, is caused by electrolysis. Electrolytic corrosion of underground structures occurs, in general, wherever current flows from the metallic structure into the earth. Many methods have been proposed or tried for reducing or eliminating damage to pipe systems and other sub-surface metallic structures due to stray earth currents from street railways. Some of these have been used widely with more or less benefit in many instances, and with apparent failure in others. There are various means by which electrolysis may be mitigated, which are applicable to the negative return of a railway system; these

include the use of an alternating-current system; use of double-trolley systems; use of negative trolley; periodic reversal of trolley polarity; methods of construction and maintenance of way; grounding of tracks and negative bus; uninsulated negative feeders; insulated negative feeders without boosters; insulated negative feeders with boosters; use of three-wire systems; and location of power houses and sub-stations.

Electrolyte. An electrolyte may be generally defined as a conducting medium in which the flow of electric current is accompanied by the movement of matter. An ionized solution which is used to conduct an electric current is an electrolyte. The liquids in a primary cell, a storage battery, an electroplating bath, are all electrolytes. See also Ionization.

Electrolytically Assisted Grinding. In this method, a conventional metal-bonded diamond wheel is employed and the work and the wheel are flooded witn an *electrolyte* (a highly conductive fluid). A steady electric current is maintained through the electrolyte between the wheel and the work. According to one explanation, the diamond particles act as insulators to separate the wheel from the work and, as the work surface disintegrates due to electrolytic action, the diamonds scrape particles of metal away. There is virtually no wear on the diamond wheel.

See also mention of electrical-discharge grinding under Electrical Discharge Machining.

Electrolytic Copper. This is copper that has been refined by the electrolytic method. Such copper ordinarily contains 99.9 per cent of pure copper and has an electric conductivity of about 97 (silver = 100). The electrolytic method for refining copper consists simply in electrolytic deposition of copper on the cathode while the impurities fall to the bottom of the tank with the slime. On account of its purity, electrolytically deposited copper demands a higher price than other copper, except Lake Superior native copper.

Electrolytic Refining. The process of electrolytic refining consists in electrolyzing anodes of the impure metal in a solution of some suitable salt of the metal, starting with cathodes of the pure metal. The metal to be refined dissolves at the anode, passes through the solution, and is deposited on the cathode in a higher degree of purity. The impurities are separated from the principal metal both at the anode and at the cathode. The most important metal refined by the electrolytic process is copper. Copper is refined to recover the valuable impurities, such as gold, silver, and platinum, and to increase the electric conductivity of

the copper, for use in electric machines and the transmission of power. Very small amounts of impurities considerably reduce the conductivity. A solution of sulphuric acid and copper sulphate is used in copper refining as the electrolyte. To this mixture, from 0.01 to 0.02 per cent of glue is added so as to cause the copper to be deposited more evenly.

Electromagnetic Hardness Testing. With an electromagnetic hardness testing instrument it is possible to determine the hardness of ferromagnetic metals, such as iron and steel, through the magnetic capacity of the metal. The action of the instrument depends upon the following laws, which hold with every variety of iron and steel: The magnetic capacity is directly proportional to the softness of molecular freedom. The resistance to a feeble external magnetic force is directly as the hardness or molecular rigidity. It has been shown, by direct experiments, that the molecules of iron are magnets, and that the cohesive force of each molecule is governed by the magnetic force. The cohesive force of the molecules determines the strength and properties of the metals; consequently, when the respective governing forces are measured, the true value of the quality of the metal will be determined.

Electromagnets. A conductor carrying an electric current creates a magnetic field around it. If the wire or conductor carrying the current is wound in the form of a loop, the magnetic field intensity inside of the loop will be much greater than that outside, because the magnetizing force of the entire loop is concentrated within that space. If several turns are made, forming a coil, each turn will add its share of magnetizing force, and produce a field of strong intensity inside of the coil. Now, if an iron bar is placed in the center of this coil, it will be magnetized, the total flux being greatly increased. The combination of the coil and iron core is called an *electromagnet*. The winding need not be distributed over the whole core, but may be concentrated in a coil in any convenient manner; and either a large electric current and a few turns of wire or a small current and many turns of wire may be used to produce the same amount of magnetizing force. An electromagnet has poles the same as a permanent magnet. The poles will depend upon the direction of the winding and the passage of the current through the conductor.

The field poles of electric motors and dynamos are electromagnets. Electromagnets are used also where there is a relatively small movement of the armature and a small air gap in relay mechanisms, such as for operating telephones, electric horns, bells, controller mechanism, automatic switches, etc. They are also used extensively on switchboards of both direct and alternating cir-

cuits, and are seen in operation in almost every manufacturing plant. Direct-current magnets have soft iron cores, and their armatures do not require any pole-shading devices like the alternating-current magnets.

Electromagnets for Alternating Current. Some electromagnets are designed to utilize alternating current. The pole shader in an alternating-current magnet is a short-circuiting ring or coil embedded in the pole face to retard the time-phase relation of the magnetic flux within the ring so that there is, at every instant, enough magnetism to hold the magnet closed. Magnets having two and three separate windings are used on two- and three-phase circuits to provide a constant pull at any moment of operation.

Electrometallurgy. Metallurgy may be defined as the art of extracting metals from ores, and refining them to the purity required for commercial purposes. Metallurgical operations are, in general, chemical operations, because ores, with few exceptions, contain the metals as chemical compounds, and, therefore, it is usually necessary to decompose the compounds by chemical reagents. *Electrometallurgy* is the art of utilizing the electric current in obtaining metals from their ores or for refining them for industrial purposes. The methods used in electrometallurgy may be divided into electrolytic and electrothermal. Each of these methods embrace several processes.

Electrometer. An electrometer is an electrical instrument for measuring differences of potentials. This instrument operates by means of electrostatic forces giving the measurements either in arbitrary or in absolute units. There are three classes of electrometers: 1. Repulsion electrometers. 2. Attracted-disk electrometers. 3. Symmetrical electrometers.

Commercial types, known as electrostatic voltmeters are used for high-voltage measurements.

Under certain conditions electrometers may be used to measure very small amounts of power and are then designated as electrostatic wattmeters. See also Electroscope.

Electromotive Force. The work done in moving a charge of electricity along any path or circuit in an electric field is defined as the *electromotive force* acting along that path.

A battery, a generator, a thermocouple, or any other device which acts as a source of electrical energy, actually provides a difference in level of electrical energy (potential) between two or more terminals. If a suitable path (conductor or circuit) is provided between the terminals of such a device, then energy will flow from the "higher" to the "lower" level (potential).

The electromotive force of a device then manifests itself as the means for causing, or tending to cause, the flow of electricity (current) from one terminal to another.

When the source of electromotive force is a battery, the electric energy is derived from the change of free energy accompanying the chemical reaction that occurs in the battery. When the electromotive force is provided by a thermocouple, the electric energy is derived from the heat that is absorbed at the hot junction (Peltier effect), and to some extent from heat absorbed at those parts of the leads where there is a temperature gradient (Thomson effect). When the electromotive force is provided by a changing magnetic flux through the circuit, as in a dynamo generator or in the output circuit of a transformer, the energy is derived from the energy of the magnetic field whose changing relation to the circuit gives rise to the electromotive force.

A potential difference may or may not represent an electromotive force. If it is the result of the passage of current through a resistance, for example, it merely represents a drop in potential, and not electromotive force. Wherever there is an electromotive force, however, there is always a potential difference.

In order to originally create a potential difference between two terminals of a device acting as a source of electromotive force, work had to be done inside the device in the conversion of mechanical, thermal, or chemical energy into electrical energy having different potential levels. The electromotive force between the two terminals is a measure of this work. If it were considered that the difference in energy level was actually created not by mechanical, thermal, or chemical energy being converted inside the device, but by the movement of charges of electricity through an external circuit from one terminal to the other, the work done per unit charge would be equivalent to the electromotive force established between the two terminals. Or, to put it in different terms, the electromotive force between these two terminals represents the amount of energy available between them per unit quantity of electricity or charge.

Electromotive force is measured in volts; and from the standpoint of "work done" or "energy available," one volt equals one joule of energy per coulomb quantity of electricity. If a source of electromotive force were connected to an external circuit of homogeneous resistance at constant temperature and a continuous current flowed through this circuit, then the electromotive force in volts is equal to the current in amperes times the resistance in ohms.

Electron. An electron is a stable elementary particle (constituent of matter) having a negative charge of -4.8×10^{-10},

electrostatic unit or -1.6×10^{-19} coulomb, and a mass approximately equal to 9.1×10^{-28} gram, which is about 1/1836 the mass of a proton or neutron. Each atom consists of a nucleus, which has a positive charge, surrounded by one or more electrons.

Electronic Tubes. An electronic tube is an electrical device consisting of an enclosure, usually of glass or metal, from within which the contained atmosphere has been evacuated to a high degree (and which may or may not be replaced by some kind of gas) and a number of metal elements called electrodes which are supported at various distances from each other within the enclosure. Electrical connection with these electrodes is usually made through a sealed base or cap to terminals which may take the form of prongs. These permit quick insertion in and removal from a holding socket, so that damaged or worn out tubes may be replaced easily.

Electronic tubes are used for a wide variety of purposes and their design is highly specialized and adapted to their intended function.

When used as *rectifying tubes* (for conversion of alternating current to direct current), they usually have two electrodes (cathode and anode) between which the passage of current is unidirectional. A third element, or grid, is sometimes incorporated to control the starting of the unidirectional current flow. Three-element types may also be used in inverter circuits for the conversion of direct current to alternating current.

When used in radio or communication equipment as *detectors*, *amplifiers*, *modulators*, and *oscillators*, there are one or more additional elements present which may be placed between the anode and cathode to control the current flow. Only an exceedingly small variation in the potential of the controlling element or *grid*, as it is sometimes called, is needed to effect relatively large changes in the current flow between anode and cathode. These types of tubes may be used as very sensitive relays.

X-ray tubes are quite different in design as compared with rectifying or communication types of electronic tubes. In X-ray tubes the anode and cathode are separated by a much greater interval and a third element in the form of a target is introduced and this is electrically connected to the anode. The stream of electrons which constitutes the current flow between cathode and anode strikes or "bombards" the target causing the emission of rays of exceedingly short wave length (shorter than ultra-violet light) and of high penetrating power, i.e. ability to pass into or through substances of considerable density such as metals. The wave length and penetrating power of these rays is a function of the density

of the metal in the target and the magnitude of the potential difference between anode and cathode. Notable developments have been made in the design of X-ray tubes operating at exceedingly high voltages and having deep penetrating power.

In *cathode ray tubes* the electronic stream or *cathode ray* is directed and focused into a beam which falls upon a fluorescent screen at the end of the tube. In impinging upon this screen the cathode ray causes a luminous spot of varying intensity to be formed. By means of additional elements which may take the form of plates (for electrostatic control) or coils (for electromagnetic control) this beam may be made to move longitudinally and horizontally across the luminous screen in synchronism with the electrical impulses of the circuit in which the tube is connected. Thus a pattern may be traced in the form of a sine wave or some other wave shape when the tube is used in an electronic oscillograph or a complete picture may be produced by rapid "scanning" as in the case of a television tube.

In *phototubes* a target of light sensitive metal is provided as one element in the evacuated or gas filled enclosure. Usually the tube itself is covered or shielded from light except for a single aperture of glass or quartz. When light passes through this aperture and falls upon the target (cathode), a stream of electrons is emitted from the target and, in passing to the other element of the tube (anode) and around through the external circuit connecting the two elements, a feeble electric current is, in fact, created. Thus, these tubes may be used wherever the function of converting light impulses into electrical impulses is needed, as in meters for the measurement of light intensities, light relays for the protection of machine operators, regulation of equipment, lighting systems, etc., and as "scanning" tubes for picking up various scenes for transmission by television or wired picture transmission.

Electronic tubes may be divided into two broad classes according to their gaseous content: *High vacuum tubes* are those which have been evacuated to such a degree that their electrical characteristics are essentially unaffected by gaseous ionization. *Gas-filled tubes* are those in which the pressure of the contained gas or vapor is such as to affect substantially the electrical characteristics of the tube.

Electronic Tubes, Industrial Applications. Electronic tubes are being used for a wide variety of functions in industry such as counting, indicating, limiting, actuating, measuring, inspecting, sorting, time control, color matching, regulating, signaling and protection of operators and machines. They are especially adapted to making certain types of measuring devices entirely

automatic and to increasing the precision and consistency of such instruments under manual operation. Electronic gages are used for measurement down to 0.00001 inch and inspection gages which automatically measure small parts for length, concentricity and hardness utilize electronic tubes. The phototube is useful in controlling electric motors and motor-driven equipment, heat processing furnaces, lights and the timing of resistance welding operations.

One interesting function is the continuous inspection of sheet steel as it passes through a shearing line. Light beams are directed on the moving sheet in such a way that when minute holes, usually imperceptible to the eye, appear, light passes through them and strikes the phototube causing the control circuit of the shearing machine to be actuated. Textile looms are equipped with phototube controls for stopping the operation when a thread breaks (see illustration). Light targets are suspended from each thread and when a thread breaks, its target drops and interrupts the light beam focussed on a phototube. This provides the controlling means for stopping the loom. Protection of machine operators where parts must be manually inserted and removed is accomplished by establishing a "curtain of light" around the working area of the machine, so that if interrupted by the worker or any object while the machine is in operation, the phototube operates immediately and the machine is stopped. This "curtain of light" is made possible by means of several phototubes lined up behind a continuous row of lenses. A similar arrangement is used to prevent machines from continuing their operation before a previously processed part is removed, thus protecting both machine and product.

The so-called gas-filled electronic tubes find a wide field of application. They are used for voltage control and regulation, for manual or automatic speed control where stepless, accurate regulation is necessary. For example, tube control is used to correlate the speeds of various sections of rubber process conveyors to maintain a given loop of rubber sheet between conveyor sections. Another application is for varying over wide ranges the speed of direct-current motors driving frequency changers which supply power to high-speed textile motors, and for maintaining the speed of motors within narrow limits at any given setting regardless of wide load changes. The use of vapor-discharge control tubes for the control of power flow to resistance welders has revolutionized the method of fabrication of many high-production units such as refrigerators, cans, vacuum tubes, etc. The control of light by the vacuum-tube-reactor dimming method is recognized as most efficient and flexible. X-ray tubes are now being utilized in equipment designed especially for the examina-

tion of castings and large machine parts where the detection of hidden flaws is important.

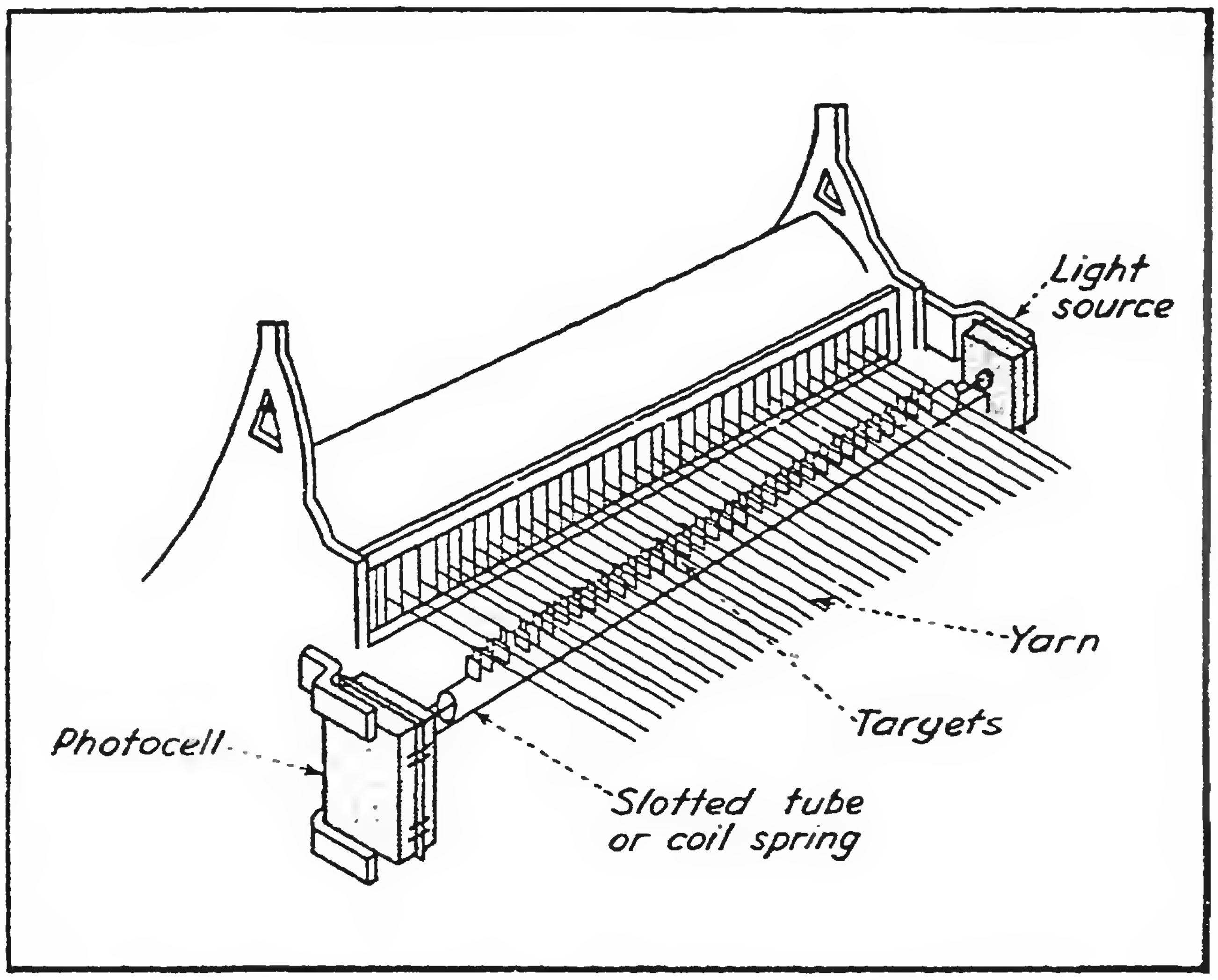


Photo-electric Control of Textile Machine

Electronic Tubes, Industrial Types. In the class of high-vacuum tubes for industrial purposes, there may be mentioned the kenotron, the phototube, the pliotron, and the magnetron. In the class of gas-filled tubes for industrial purposes, there is the phanotron, the glow tube, the pool tube or tank, the phototube, the thyratron, the grid glow tube, the grid pool tube or tank, and the ignitron.

The *kenotron* is a high-vacuum thermionic tube in which no means is provided for the control of unidirectional current flow.

The *phototube* is a vacuum tube in which the electronic emission is produced directly by radiation falling upon an electrode. A high-vacuum phototube is one which is evacuated to such a degree that its electrical characteristics are essentially unaffected by gaseous ionization.

The *pliotron* is a high-vacuum thermionic tube with one or more electrodes employed to control unidirectional current flow.

The *magnetron* is a high-vacuum thermionic tube in which a magnetic field is employed to control the unidirectional current flow.

The *phanotron* is a hot-cathode, gas-discharge tube in which no means is provided for controlling the unidirectional current flow.

The *glow tube* is a cold-cathode, gas-discharge tube in which no means is provided for controlling the unidirectional current flow.

The *pool tube* (or tank) is a gas-discharge tube (or tank) with a pool-type cathode (liquid or solid) in which no means is provided for controlling the unidirectional current flow.

The *phototube* of the gas-discharge type is one in which a quantity of gas has been introduced, usually for the purpose of increasing its sensitivity.

The *thyratron* is a hot-cathode, gas-discharge tube in which one or more electrodes are employed to electrostatically control the starting of unidirectional current flow.

The *grid glow tube* is a cold-cathode, gas-discharge tube in which one or more electrodes are employed to control electrostatically the starting of unidirectional current flow.

The *grid pool tube* (or tank) is a gas-discharge tube (or tank) with a pool-type cathode (liquid or solid) and with one or more electrodes provided for controlling electrostatically the starting of unidirectional current flow.

The *ignitron tube* is a gas-discharge tube (or tank) with a pool-type cathode (liquid or solid) in which an ignition electrode is employed to control the starting of unidirectional flow of current in each operative cycle.

Electron Metal. Electron metal, a very light constructional metal, was first placed on the market in 1909 by the Griesheim-Elektron works in Germany. It is an alloy of magnesium, having a specific gravity but two-thirds that of aluminum, with great tensile strength and machinability. The fact that it contained magnesium caused much prejudice against its use at first, most people only knowing that metal in the shape of wire or powder of great combustibility. It is true that electron metal, after melting, is very oxidizable, its blinding white light being characteristic, but, as its melting point is as high as that of aluminum—about 1200 degrees F.—its combustibility need not be considered unless the metal is to be used under exceptional conditions as to temperature. Of this the greatest proof is afforded by its use in internal-combustion engine pistons, where it is constantly exposed to the exploding gases. Its chemical character restricts its sphere of application, being unsuitable for articles which are in constant contact with running water, acids, or acid solutions. When exposed to the atmosphere, a gray coating of rust forms but this coating does not, like iron rust, extend further into the

metal, which is, in the case of electron metal, saved from further attack. The application of oil or grease entirely prevents the formation of such a coating.

Electroplating. Electroplating is the art of making electrolytic depositions of one metal on another for the purpose of improving the appearance of the metal covered, or the wearing qualities, or both. In order to deposit one metal on another in a smooth, firmly adhering layer, the surface to be covered must be perfectly clean and the electrodeposition must be carried out under the proper conditions. There are five factors that determine whether or not the metal deposit is of a smooth, firm, adherent character: 1. The kind of dissolved salt from which the metal is deposited. 2. The strength of the solution. 3. The temperature of the solution. 4. The current density on the cathode. 5. The thickness of the deposit. The operation of plating consists of the following: 1. Cleaning and smoothing of the surface to be plated. 2. The electrodeposition of the metal. 3. The final polishing.

Two laws which govern the process of electroplating were established by Faraday. These state (1) the mass of a substance liberated or deposited by an electric current is proportional to the current and to the time it exists, and (2) when the same strength of current is sent through different electrolytes, the masses of the different substances deposited or set free in the same length of time are proportional to their respective chemical equivalents.

The tanks for electrodeposition are usually made of wood lined with lead or of welded steel, with or without a lining, depending upon the type of plating being done. The object to be plated forms the cathode, while the anode supplies the plating metal. The anodes are sometimes fitted with filter bags to collect any sludge resulting from impurities.

The anodes and cathodes are suspended from metal bars running lengthwise of the tanks. The cathodes are suspended between two rows of anodes so that the metal will be deposited evenly on both sides. The cathodes are suspended from the metal rods by means of soft copper wire. Very small objects, such as tacks, pins, and screws may be placed in a metal basket and suspended from the cathode rod, a drum with nonconducting, perforated walls may be used or in the case of large-scale automatic production, a continuous conveyor may be utilized.

The water used to make up the plating solutions should be clear and pure; usually the water supply of modern cities is sufficiently pure for the purpose. The chemicals used should also be of a fairly high grade of purity. The thickness of the deposit depends upon the current density and the duration of the plating. The value of the current density can be varied only within certain

limits that have been found to give good deposits. In plating an uneven surface, more metal deposits on the elevated portions and on the edges than in the depressions; the variation in thickness may be as much as 1 to 10 for different parts of the surface.

Nickel is extensively used in electroplating because of its good wearing qualities, pleasing appearance when polished, the fact that it is not blackened by sulphur compounds, and its very slight tendency to oxidize even in the presence of moisture. It also makes an excellent under-coating for plating with other metals.

Chromium has been utilized widely where a lasting bright and highly corrosion-resistance finish is desired. It is most often plated over a nickel under-coating.

Cadmium is also used to a limited extent for protective purposes.

Copper has been superseded to a considerable degree by other types, although it is frequently used as an under-coat for nickel.

Zinc is used for industrial protective purposes.

Color-plating is also more or less common. In one process, an entire range of colors may be obtained from a single bath, depending upon the length of time that the article remains in the bath. See also Ionization.

Electropolishing. Electropolishing or electrolytic polishing, as it is more commonly called, is a method of polishing irons, steels, aluminum, zinc, copper, etc. by treating the piece to be polished anodically in an electrolytic bath with sufficient current density.

Electro-Positive. Of the various methods used to protect iron from corroding or rusting, the application of a zinc surface is one of the most effective. This is due to the fact that zinc is one of the few moderate-priced metals which is electro-positive to iron. To understand the meaning of this statement, it is necessary to know what takes place during the corrosion of a piece of iron or steel that is protected by a coating of some other metal. The corrosive action is started by the setting up of a galvanic electric current, which results in carrying metal to the negative pole of the electrolytic cell. In the case of zinc, which is electro-positive to iron, a galvanic action of this kind causes a slight depletion of the zinc at points where such an action is proceeding, but does not damage the iron. With iron or steel products covered with a coating of some metal which is electro-negative to iron, the result of such a galvanic action would be the reverse; namely, there would be a depletion of the iron beneath the coating of the second metal which covers the work. It is of interest to note that the corrosive action caused by a galvanic current can only

take place where there is a flaw in the coating of zinc or other metal with which the iron is covered, that allows moisture to gather. But as it is practically impossible to produce a coating in which there are not at least a few very small openings, the effect of the galvanic action that takes place at such points becomes a matter of importance.

Electroscope. The electroscope is an instrument used for detecting the presence of an electric charge, or, in other words, differences of electrical potential or electrification. One of the earliest forms of electroscope consisted of a light metallic needle balanced on a pivot the same as a compass needle. An improvement on this type consisted in simple forms of repulsion electroscopes, in which two similar electrified bodies repelled each other. The uses of the electroscope are to ascertain if any body is in a state of electrification and to indicate whether the charge is positive or negative. See also Electrometer.

Electrowinning. Electrowinning is the electrodeposition of metals or compounds from solutions derived from ores or other materials using insoluble anodes.

Electrum. Same as German Silver.

Element. In chemistry, an element is a substance which consists of chemically united atoms of one kind. The substance cannot be changed by chemical action into some other substance or substances, except by the addition of some other element that can combine with the atoms of the original element; hence, iron, lead, sulphur, hydrogen, etc., are elements.

Elkonite Electrodes. Copper is ideal as electrode material, insofar as electrical conductivity is concerned, but for many classes of service it is lacking in strength and durability and for certain applications its use is entirely impracticable. The pressures which must be applied for some welding operations are so high that copper electrodes are rapidly compressed and distorted, especially after being annealed by the heat incident to welding; consequently, the contact area is increased, thus decreasing the resistance to current flow and the amount of heat generated. As a result the quality of the weld is impaired, unless provision is made for increasing the amount of current to offset the increase in contact area. In other applications where the electrodes are utilized to accurately locate the parts to be welded, the deformation of the electrodes due to clamping pressures and compression of the metal, results in gradually changing the location of the parts so that the work is done inaccurately.

The difficulties referred to in connection with copper electrodes, have been overcome by the introduction of electrodes composed of

tungsten and copper in proportions that are varied to suit the class of service. This electrode material is known as "Elkonite." It is not a true alloy, but rather a mechanical mixture of tungsten and copper. For some purposes there is 50 per cent of tungsten and 50 per cent of copper, whereas for other applications the tungsten content is increased up to 80 per cent.

Elkonite electrodes are from about 100 to approximately 500 times more durable than copper electrodes. They are especially recommended for operations requiring either higher compressive strength than copper, or a somewhat higher resistance. The latter, for instance, is a factor in welding satisfactorily certain non-ferrous metals such, for example, as aluminum. This type of electrode consists of an Elkonite insert only, the main body being of copper.

Ellipsograph. The ellipsograph is an instrument employed for drawing ellipses on the drafting-board. A number of different designs have been developed, some of which are obtainable as commercial products in the market.

Ellipsoid. An ellipsoid is a solid body of such shape that all the sections passing through its center are ellipses. If the ellipsoid is formed by an ellipse rotating about its major axis, all the sections on planes parallel to the minor axis of the generating ellipse will be circles, and the solid body so formed is known as an *ellipsoid of revolution*, or a *spheroid.*

Elliptical Chucks. Elliptical chucks are used to a limited extent in machine and tool work and much more extensively in woodworking and metal spinning. In die-making, elliptical chucks are useful for turning or boring oval punches and dies. For woodworking, elliptical chucks are used for such operations as the turning of oval frames and in connection with ornamental work. Chucks of this type are also used for metal spinning in order to produce the various elliptical and oval shapes in which sheet metal parts are made.

Operation: A combined rotating and lateral motion is derived from some mechanism in order to generate the elliptical curvature. The rotary motion may be given to the work and the lateral motion to the tool, but the most common arrangement consists of a special form of chuck which is so designed that the combined motion is imparted to the work, the turning or boring tool being held and used in the usual way. These elliptical chucks differ more or less in their construction, but the fundamental operating principle is the same. The chuck is essentially a rotary compound slide, the action of which is regulated by an adjustable eccentric ring for obtaining an ellipse with the required major and minor dimensions.

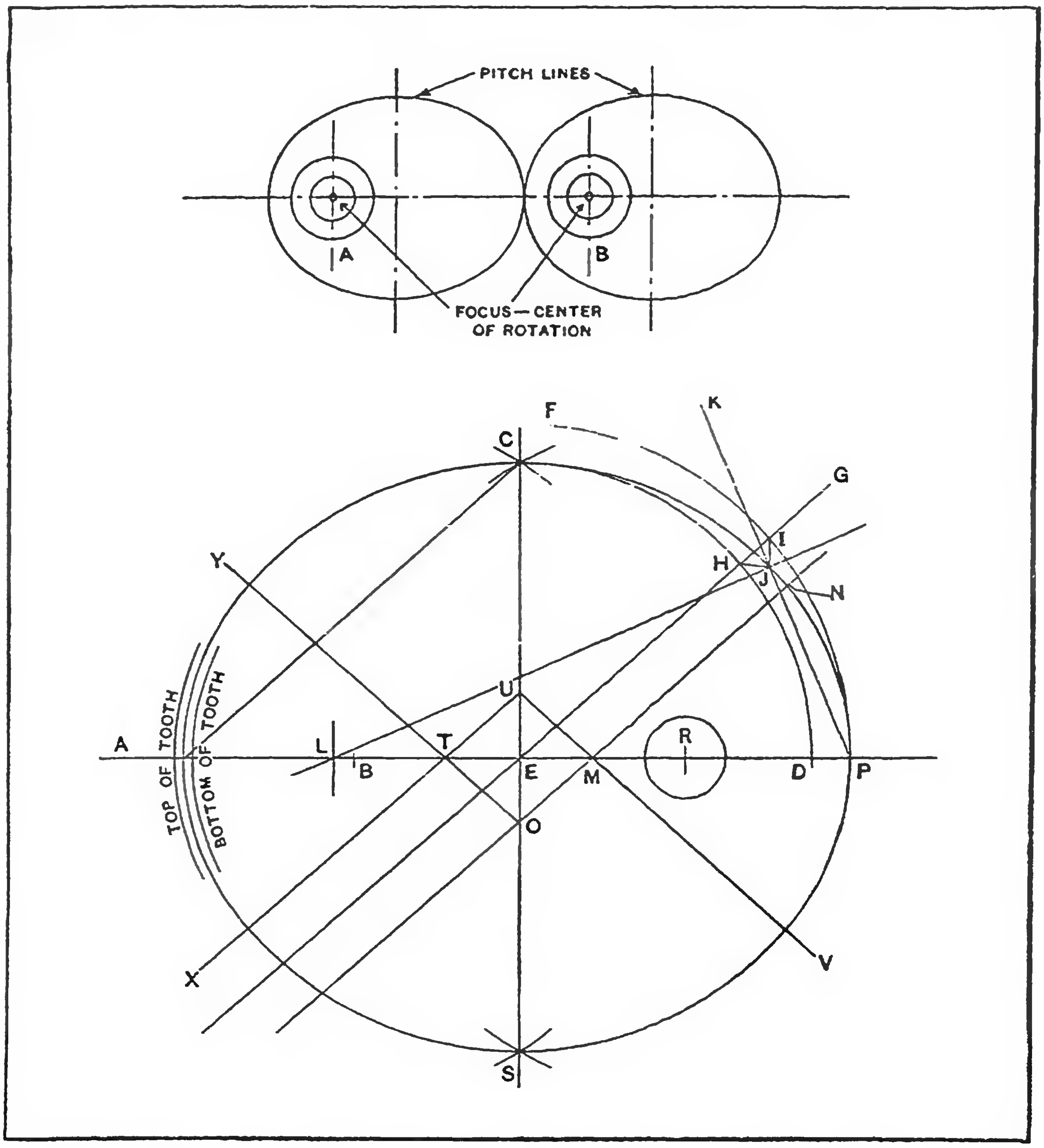


Fig. 1. (Upper Diagram) General Arrangement of Elliptic Gears. (Lower Diagram) Laying out an Ellipse by Means of Circular Arm

Elliptic Gears. Gears of this type provide simple means of obtaining a quick-return motion but they present a rather cumbersome manufacturing problem and, as a general rule, it is preferable to obtain quick-return motions by some other type of mechanism. When elliptic gears are used, the two gears that mesh with each other must be equal in size, and each gear must revolve about one of the foci of the ellipse forming the pitch line, as indicated by the upper diagram, in Fig. 1. By the use of elliptic gears so mounted, it is possible to obtain a variable motion of the driven shaft, because the gear on the driving shaft, while revolving one-half of a revolution, will engage with only a small portion of the

circumference of the driven gear, while during the other half of its revolution, the driving gear will engage with a great deal more than one-half of the total number of teeth in the driven gear; hence, the cutting stroke of a machine tool, for example, may be made to have a slow motion, while the return stroke is at a rapid rate. The ellipse has two points, each of which is called a *focus*, located as indicated at *B* and *R*, lower diagram. The sum of the distance between the foci and the elliptic curve is constant at all points and is equal to the longer or major axis *CD* of the ellipse. On account of this peculiarity of the ellipse, two equal ellipses can be made to mesh with each other during a complete revolution about their axes, if one is mounted on a shaft at its focus *A* and the other at its focus *B*, as shown by the upper diagram.

Laying Out Elliptic Gears: The method of laying out elliptic gearing and the cutting of the teeth is an approximate process which may be done in a number of different ways. In the following, a practical case will be explained, indicating the methods that may be followed. The following general principles must be taken into account in laying out the teeth in elliptic gears: The axes must come in line at the time when the teeth that are at a maximum distance from the focus or center of rotation of one gear mesh with the teeth that are at the minimum distance from the center of rotation in the other gear, as in Fig. 1, upper diagram. In order to assure this, the teeth of one gear must be arranged to suit the location of the teeth in the other gear, so that they slip properly into mesh at the point where the axes are in alignment. In addition, it is desirable to have the teeth located in the two gears exactly alike, so as to make it possible to cut them at the same time, while mounted on the same arbor. To obtain this condition, a different arrangement of the teeth is necessary, according to whether the teeth are odd or even in number. If the number of teeth is odd, the major axis of the ellipse should bisect a tooth at one end and a tooth space at the other, as shown in Fig. 2. If the number of teeth is even, one tooth must be tangent to the major axis at the pitch line, as shown in Fig. 3. Little, if any, mathematical treatment is required for the laying-out of elliptic gears that are to be cast from patterns.

Obtaining the Pitch Line: Referring to Fig. 1, lower diagram, the major axis *AP* is equal to the distance between the centers of the shafts on which the gears are to run. The hub of the gear is placed at one of the foci *B* of the ellipse. The positions of the foci *B* and *R* are determined by the ratio of quick return desired; that is, the foci points *B* and *R* should be so placed that the distance *PR* is in the same ratio to *AR* as the given quick-return motion desired in the gearing. For example, in a gear, the major axis of which is 8 inches, a given quick-return motion of 1 to 3 is

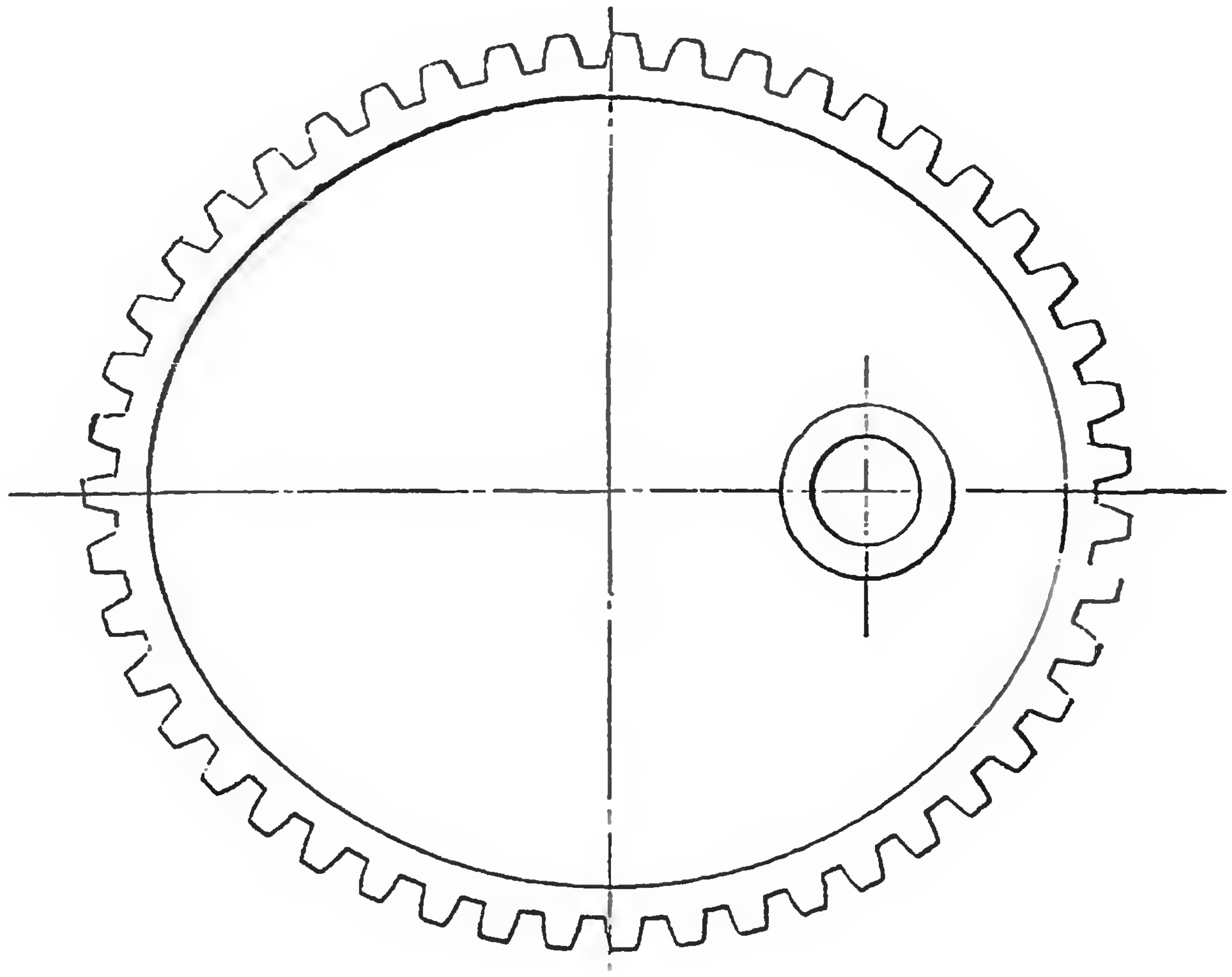


Fig. 2. Relative Position of Teeth and Axes when Number of Teeth is Odd

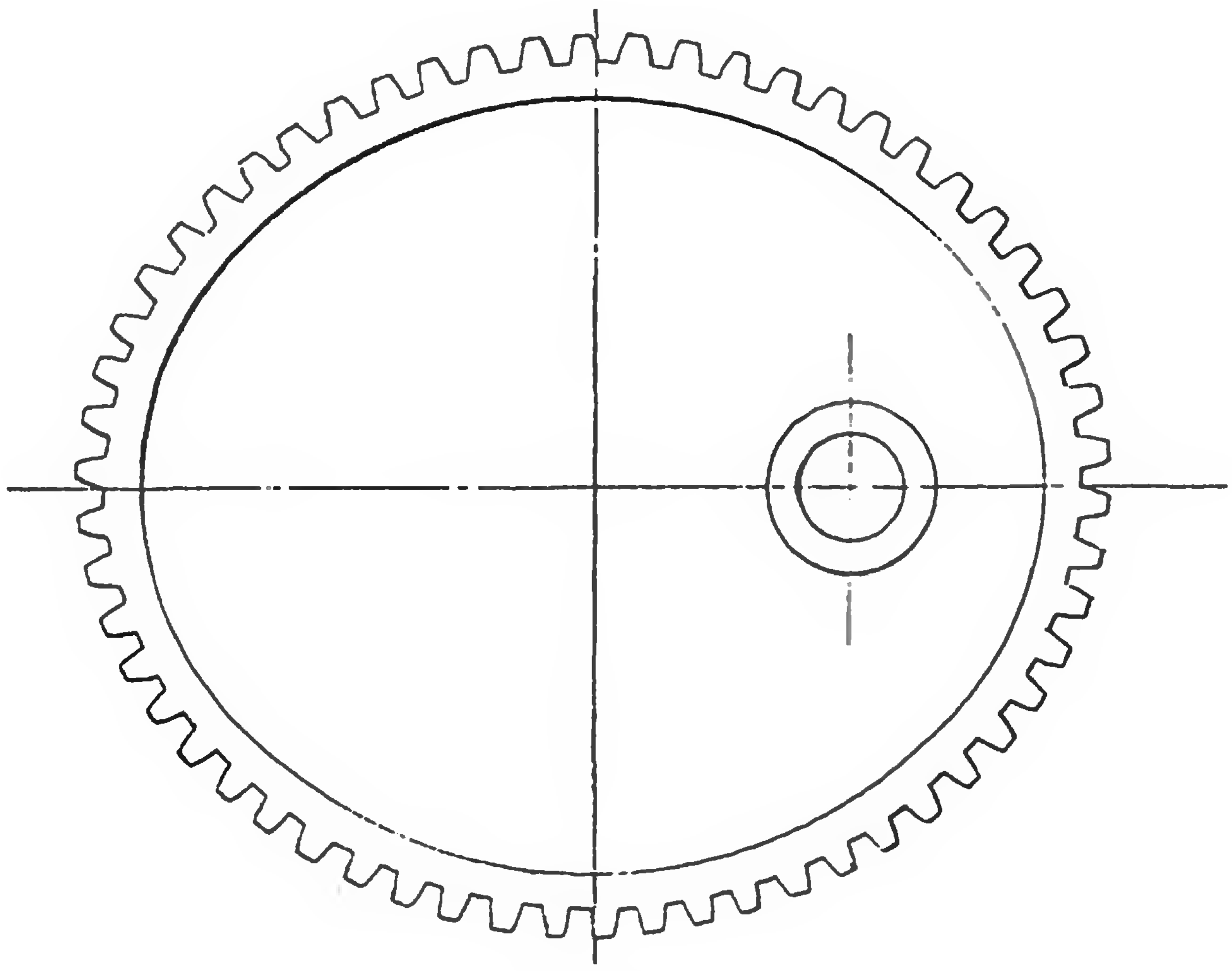


Fig. 3. Relative Position of Teeth and Axes in an Elliptical Gear with Even Number of Teeth

desired; then PR would equal 2 inches and AR would equal 6 inches, because $2:6 = 1:3$. Having determined the major axis and foci of an elliptical gear, the length of the minor axis may now be found by using one of the foci B or R as a center, and, with a radius equal to one-half the major axis, cutting the line of the minor axis at C and S.

When the minor axis has been found, proceed as follows to construct the ellipse: With the point E, where the major and minor axes intersect, as a center, and a radius equal to EC, draw arc CD; then, with EP as a radius, draw arc PF. Now draw a line AC as shown, and through E draw a line EG parallel to AC. From the intersection of the line EG with the arcs CD and PF, as shown at points H and I, draw lines parallel to the axes of the ellipse which will intersect at point J. Draw line PK through J, and at J erect a perpendicular to line PK, intersecting the major axis at L. Next bisect LP, thus obtaining point M. Through M, draw a line MN parallel to AC, intersecting the minor axis at O; lay off ET and EU equal to EM and EO, respectively, and draw UMV, UTX, and OTY. Now, using M as a center and a radius equal to MP, draw arc NPV. Then from center U, with a radius equal to US, draw arc VSX. From center T, with a radius equal to TA, draw arc XAY, and, from center O, with a radius equal to OC, draw arc YCN. If the work has been done carefully, all the arcs will match, giving an approximately true ellipse.

Spacing the Teeth: Having obtained the pitch line of the gear in the manner described, the completion of the pattern by the forming of the teeth must next be considered. The following method has been selected because of its simplicity and the fact that no special jigs or tools are necessary in making the master pattern. The pitch of the tooth must first be decided. In the case just considered, 8 diametral pitch was selected. The distance of the top and bottom of the tooth from the pitch-line is now laid off on the drawing and shown by arcs drawn parallel to the pitch-line from the centers M, O, T, and U, Fig. 1. The line of the top and bottom of the tooth being drawn as directed, the teeth may now be spaced off on the pitch circle. The simplest method for doing this is to use the dividers, which should be set at one-fourth the circular pitch of the tooth. This may be obtained by dividing 3.1416 by four times the diametral pitch of the gear. For example, if the diametral pitch is 8, then $\frac{3.1416}{8 \times 4}$ equals one-fourth of the circular pitch. This distance being found, set the dividers to it and follow the outline of the pitch circle very carefully, marking every fourth step.

By using steps of one-fourth the circular pitch as recommended, the pitch-line may be more closely followed and, at the same time, the width of the tooth and space, as well as their center-lines, will be obtained. It is now a simple matter with a radius of suitable length to lay out the teeth which should be made with a simple curve, the same as commonly used on plain cast gears. This curve may be closely approximated by using a radius equal to one-fourth of *OC*.

If it is found after spacing the teeth that their number is even, the teeth must be located with relation to the major axis as shown in Fig. 3, but, if the number of teeth is odd, then the major axis must bisect a space and a tooth as shown in Fig. 2. This is necessary in order that the two gears shall mesh, as already explained. It is evident that when the teeth are spaced by dividers, the spacing will not generally come out exact at the first trial. The spacing must then be increased or decreased slightly until the perimeter of the ellipse is found to be evenly divided. It would be possible to obtain the approximate length of the perimeter by one of the empirical formulas found in handbooks for this purpose, and to find the number of teeth by dividing the circular pitch into the length of the perimeter; but, as the result thus obtained would only be approximate, trial spacing with dividers would still be necessary, and little would be gained by this procedure. Hence, the method outlined is more practical than any in which the mathematical treatment is used.

Forming the Teeth: The number and location of the teeth having been determined, it now becomes necessary to form the tooth. This may be done in two ways. If no other means are convenient, the teeth may be cut directly into the pattern by hand, using an ordinary chisel and following the exact outline of the tooth as laid out in the pattern. This method, while entirely practical, is quite slow and tedious, and, where possible, the following method is recommended. Having found the center-line of the teeth on the pitch circle, project it to the base or root circle of the pattern, marking each point distinctly. Now cut away everything above the root circle and finish the pattern carefully to this line. Next, from a straight piece of clear-grained hard wood, cut a rack on an ordinary gear-cutting machine. This rack should have at least as many teeth of the same size and pitch as are required for the elliptical gear. These teeth when finished should be cut free from the rack and fastened to the elliptical gear pattern blank with wire brads and hot glue, spacing them as shown by the points previously projected to the root circle. After the glue has had time to set and the teeth are securely fastened, wax fillets should be put in and the pattern blackened and finished as is customary with all master patterns, after which iron patterns should be cast

from it. It is advisable before expending too much labor on the iron patterns to prove their accuracy by placing them on gear centers and allowing them to run together. If ordinary care has been used there should be no serious trouble, but if they seem to bind at certain points, these may be eased off with a file. On the whole, however, the patterns will be found entirely satisfactory and will give good smooth running gears.

Half-elliptic Gears: As applied to a machine tool, the elliptic gear quick-return motion has one radical fault which is that, while a slow advance with a quick return is given to the tool, the cutting stroke is not made at a uniform speed but begins with a gradually retarded motion, and then, in the last half of the stroke, the speed begins to accelerate again. In order to overcome this defect and to produce a machine with a uniform motion during the entire cutting stroke, the combination of half-elliptic and spur gearing shown in Fig. 4 may be used. The half-elliptic or oval gear shown makes but one-half a revolution to each complete revolution of its eccentric driving pinion. Therefore, half of the elliptic gear may be cut away as shown. It is mounted on the same shaft with half of a regular spur gear, the pitch diameter of which is equal to the major axis of the half-elliptic gear. On the shaft with the eccentric driving pinion, an ordinary concentric pinion may be placed, the pitch diameter of which is equal to one-fourth that of the half-spur gear. This pinion is so mounted that it will engage the half-spur gear when the eccentric pinion has swung the half-elliptic gear into the position shown in Fig. 4. At this point, the eccentric pinion ceases to drive the half-elliptic gear, owing to half of it being removed. The concentric pinion now engages the teeth of the half-spur gear, picks up the load and continues to drive it through the next half revolution of the gear shaft, or until the teeth of the working half of the half-elliptic gear are again engaged by the eccentric pinion. Owing to the difference in diameters of the half-spur gear and its pinion, the latter must make two revolutions before the eccentric pinion can again engage the teeth of its half-elliptic mate.

When the eccentric pinion picks up the load it does so at the same speed at which the concentric pinion left it, due to the fact that the short segment of the axis is equal to the radius of the concentric pinion. Now as the eccentric pinion begins to swing the half-elliptic gear around, the gear will gain speed until it reaches a point where the long segment of the axis of the eccentric pinion is opposite the minor axis of the half-elliptic gear, when it has reached the maximum speed. After that, the speed of the half-elliptic gear will gradually decrease until it again reaches that of the concentric pinion, whereupon it will be once more picked up by the concentric pinion and the same cycle will be repeated.

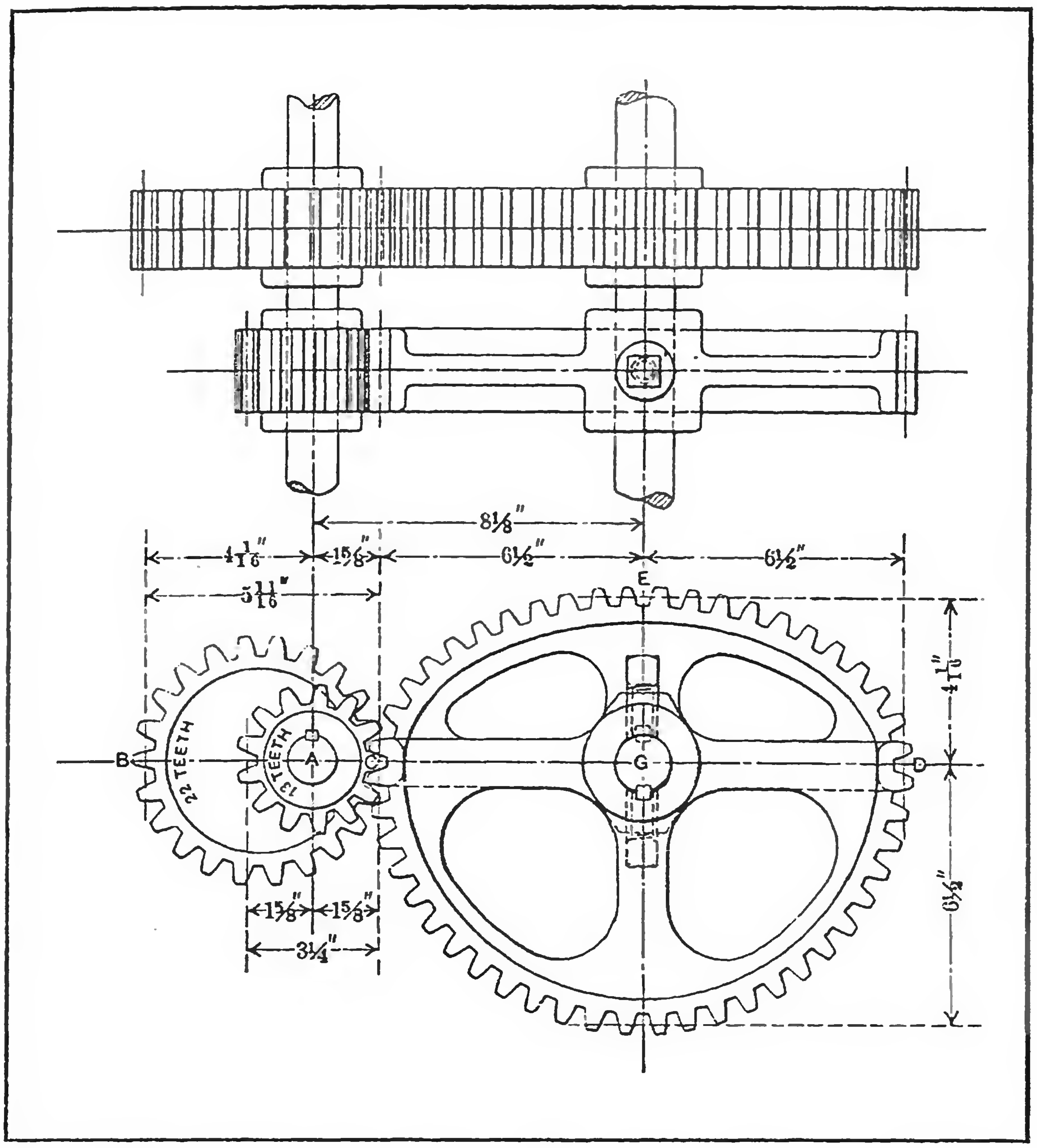


Fig. 4. Quick-return Gearing with Ratio of 2 to 1

It will be observed that for each three revolutions of the pinion shaft the half-elliptic gear shaft makes but one, and that while it takes two revolutions of the concentric pinion to cause the half-elliptic gear shaft to make one-half a revolution, the eccentric pinion will drive the half-elliptic gear the remaining half revolution while making one turn. It will also be seen that the concentric pinion drives the half-spur gear at a slow and uniform speed. After this the eccentric pinion starts to drive, the half-elliptic gear, rotating slowly at first but gaining headway, reaching the maximum and then falling back to the original slow speed. During this time the tool-head is returned with a quick motion to the starting position ready for the next cutting stroke. The ratio

of the quick return to the cutting speed must not be too great or else a jerky motion will ensue that will cause an excessive vibration in the machine. It has been found by experiment that a ratio of 2 to 1 is about the best speed at which the tool can be run, and by the combination just described this proportion is obtained with a smooth easy change from fast to slow, approaching as nearly as possible the ideal motion.

Laying out Half-elliptic Gears: The main feature of this combination of gearing is the half-elliptic eccentric pair. It may be well first to state briefly a few cardinal points that apply without change to all gears of this form. 1. The long segment (AB in Fig. 4) of the eccentric pinion in all half-elliptic eccentric pairs is equal to one-half the distance between the centers of the shafts. 2. The short segment (AC) of the eccentric pinion is equal to one-half the diameter of the concentric pinion running on the shaft with it. 3. The true diameter (BC) of the eccentric pinion equals the sum of its long and short segments (or $AB + AC$). 4. The major axis (CD) of the half-elliptic gear is equal in all cases to twice the distance between the shaft centers, less twice the short segment (AC) of the eccentric pinion. 5. The minor axis of the half-elliptic gear equals in all cases the distance between the centers of the shafts. 6. The elliptical gear, if complete, should have twice the number of teeth that there are in its eccentric driving pinion, and the number of the teeth in both the half-elliptic gear and the eccentric pinion should be even. 7. The shaft hole G of the half-elliptic gear is always placed at the intersection of the major and minor axes, or, in other words, in the exact center of the half-elliptic gear, and not at the focus, as in regular elliptic gearing.

With the foregoing rules in mind, assume 4 diametral pitch as the proper pitch for the gear teeth. As the half spur gear makes but one-half a revolution to each two revolutions of its concentric driving pinion, it naturally follows that it must have twice the number of teeth in half its circumference as are contained in the entire periphery of the concentric pinion that drives it. In other words, if the gear were a complete circle, it would have four times the number of teeth in its pitch-line that are contained in that of the concentric driving pinion. If, therefore, this circle is assumed to contain 52 teeth, then the pinion should have one-fourth that number, or 13 teeth. The pitch diameter of the larger gear would be equal to 52/4 or 13 inches, while that of the pinion would be 13/4 or $3\frac{1}{4}$ inches. As the distance between the centers of the shafts is equal to one-half the sum of the pitch diameters of the intermeshing gears running on them, it would, in this case, equal

$$\frac{13 + 3\frac{1}{4}}{2} \text{ or } 8\frac{1}{8} \text{ inches.}$$

Eccentric Pinion: Now consider the eccentric pinion. Its long segment must be equal to one-half the distance between the centers of the shafts; the short segment must be equal to one-half the diameter of the concentric pinion running on the same shaft with it. Therefore, the long segment will equal $8\frac{1}{8} \div 2$, or 4 1/16 inches, while the short segment will equal $3\frac{1}{4} \div 2$, or $1\frac{5}{8}$ inch. The true pitch diameter of the eccentric pinion is equal to the sum of its long and short segments, or 5 11/16 inches. This pitch diameter multiplied by the pitch of the tooth gives 4×5 11/16, or $22\frac{3}{4}$, as the number of teeth in the pitch circle. This is impossible, and as it is necessary that the number of teeth in the eccentric pinion be even, 22 teeth will be used. This will necessitate spacing them slightly farther apart.

Half-elliptic Gear: The major axis of the half-elliptic gear is the same as that of the half spur gear, or 13 inches. Its minor axis is equal to the distance between the shaft centers, or $8\frac{1}{8}$ inches. Having these figures to work with, proceed to construct the elliptic pitch-line of the gear. After having obtained the pitch-line, lay off the tops and bottoms of the teeth parallel to it and draw in the teeth, using the methods already explained for regular elliptic gears. It is essential, in laying out the half-elliptic gear, that both ends of the major axis should bisect a tooth space as shown in Fig. 4, owing to the fact that the eccentric driving pinion makes two complete revolutions to each one of the half-elliptic gear and so corresponding points on the opposite side of the elliptic gear should be constructed in the same manner; otherwise, the eccentric pinion, which should have a tooth at the end of both the long and short segment of its axes, as shown in Fig. 4, will not mesh properly with it. The eccentric pinion is simply a regular circular pinion with its shaft hole off center.

Elliptic Springs. An elliptic spring generally consists of a number of flat leaf springs so arranged that the supports are at both ends of the flat leaves and the loads applied in the center. The leaves are generally slightly curved in the making, giving them the shape of an elliptic arc, so that the load, when applied, tends to straighten the leaves. Elliptic springs may be either *half-elliptic*, also known as semi-elliptic, or *full-elliptic*, according to whether they are made up of one or two sets of curved leaves.

Elmore Process. The Elmore process is an electrolytic process for making copper tubes by depositing copper on a conducting cylinder rotating in an acid copper-sulphate bath. The surface of the conducting cylinder is prepared so that the copper will not stick so firmly that the tubes cannot be slipped off the cylinder when finished. The outer surface of the tube being deposited is kept smooth by frequent polishing during the deposition of copper. Copper sheets may be made by the same process by making

the cylinders on which the copper is deposited of large diameter, so that the tubes become large enough to be cut open and spread out.

Elongation and Reduction of Area. When a piece of material is tested for tensile strength in a testing machine, it elongates a certain amount before rupture takes place. This elongation constitutes an important quality in the material, as it indicates its toughness or the degree to which the material is likely to give warning before it will actually break. It is measured as the percentage of stretch or *elongation* occurring in a given length of the original piece; this length is frequently assumed as two inches. For example, if a test-piece 2 inches long is found to be 2¼ inches long after rupture, the elongation in two inches is said to be 12½ per cent. It should be noted that the recorded value of elongation for any test depends largely upon the original length selected for comparison, because the total elongation consists partly of a general extension which takes place mainly before the ultimate stress has been reached, and which is distributed fairly uniformly over the whole length of the piece, and partly of an elongation in the vicinity of the section where the rupture will occur, where the local elongation is much greater, and practically independent of the total length of the piece. At this point, the elongation is also accompanied by a marked contraction of cross-sectional area. The elongation at the time of rupture cannot be calculated, but, in every case, is found by actual tests.

A piece of material tested to failure in tension contracts or decreases in cross-sectional area at the point of rupture. The percentage of decrease of area in relation to the original normal cross-section is known as the *reduction of area.* For example, if the original cross-sectional area of a bar was 0.78 square inch, and the section, after the piece had been tested to failure, was 0.44 square inch, then the decrease of area would be 0.34 square inch and the reduction of area would be $0.34 \div 0.78 = 0.44$, or 44 per cent. The area of a round bar tested to destruction is usually computed from the mean of two diameters measured at right angles to each other. Brittle materials fail without appreciable deformation. Thus the percentage of elongation and the reduction of area in test-pieces of brittle materials are very small. As an example may be mentioned cast iron, which will break with practically no deformation.

Embossing. Embossing is the process of producing raised patterns or letters on metal surfaces. The term is also extended to the production of raised patterns on leather, paper, and other fabrics. Strictly speaking, the term should be applied only to the process of producing raised patterns or letters by means of

dies or plates which are brought to bear forcibly upon the material to be embossed.

Embossing and Coining Presses. Some embossing operations may be done in almost any kind of power press but the heaviest work requires a machine of special design, owing to the enormous pressures necessary for this branch of die work. These pressures range from a few tons up to 1000 or 1500 tons. In the knuckle-joint embossing press, the die is fastened to a slide which is actuated by means of powerful toggles. These presses are adapted for embossing silver, Britannia, brass, copper, etc., and the manufacture of medals, coin, jewelry, watches, silverware, etc.

Embossing Dies. An embossing die is used to form raised letters or an ornamental design, in relief, upon the surface of the work. An embossing die differs from a forming die in that the projections or designs made by it are comparatively small or shallow, and usually in the nature of relief work upon a surface, whereas a forming die gives the required shape to the work. The formation of lettered inscriptions, symbols, and decorative designs on all kinds of sheet-metal boxes and cans is done by embossing dies. A simple form of embossing die is one used for producing the circular ridges on the heads of tin cans, etc. Such a die would have one or more annular grooves and the punch would have annular ridges of corresponding size for forcing the metal into the die grooves. Embossing is commonly done in a die designed to cut, draw, and emboss the blank in one operation. An embossing die of this kind may be either a combination, a double-action, or a triple-action type, depending upon the nature of the work and the kind of press available.

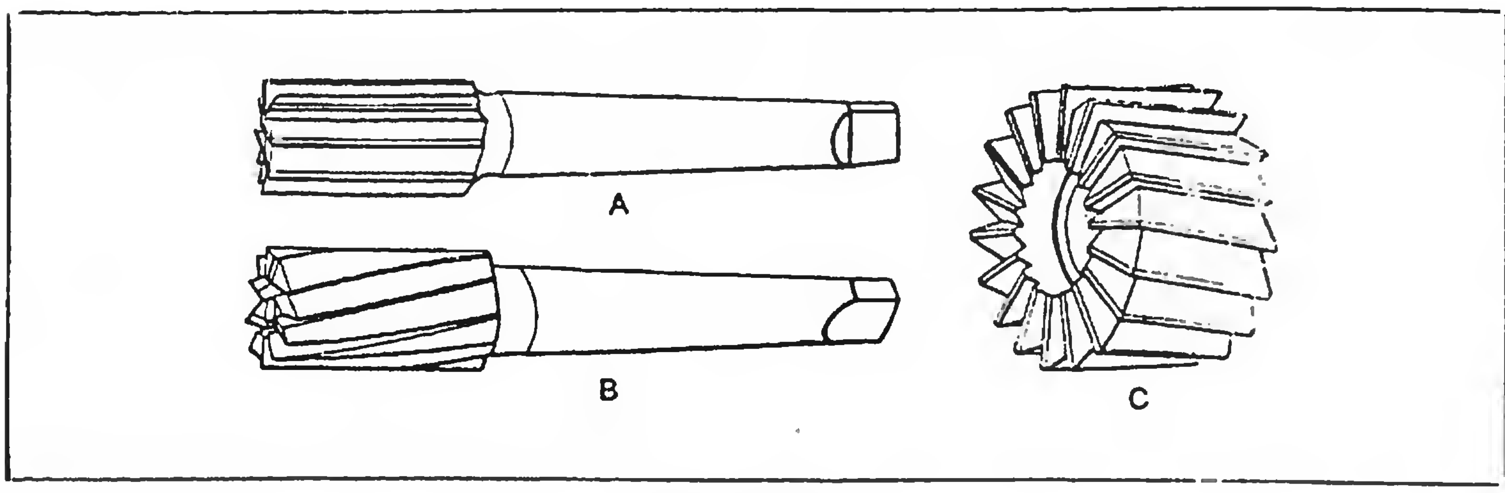
Emery. Emery is an abrasive which has been very extensively used. At one time, practically all grinding wheels were made from it, but artificial abrasives possessing superior cutting qualities are now employed for machine grinding. Emery is obtained from Naxos (an island in the Ægean Sea); from the vicinity of Smyrna, in Turkey; and from Chester, Mass. The value of emery as an abrasive depends upon the proportion of crystalline aluminum oxide which it contains, since this is the only element in emery which is hard enough to have any appreciable cutting action on metals. Naxos emery contains 63 per cent aluminum oxide; Smyrna or Turkish emery, 57 per cent; and Chester emery, 55 per cent.

E.M.F. This is an abbreviation for electromotive force. The abbreviation *emf* has been adopted as the American Standard. See Electromotive Force.

End Angle of Hob. See Hob End Angle.

End-Milling. In the machine shop the surfaces of parts undergoing machining or processing are frequently machined with end-mills when it would not be feasible to use a cutter mounted on an arbor. The end-mill is made with radial teeth on the end as well as teeth on the cylindrical surface. Both of these sets of teeth may be used to mill the surface of the workpiece as it is moved with the machine table at right angles to the cutter. For a further description of end-mills see End-Mills.

End-Mills. End-mills, as shown at *A* and *B*, are provided with teeth both on the cylindrical surface and on the plain end surface; hence, they can cut in an endwise as well as in a sidewise direction. End-mills may be provided either with a solid shank by which they are driven, or with a hole through them in which



End-mills

an arbor fits which drives the mill. This latter type, shown at *C*, is known as a *shell end-mill.*

End-mill Flutes: Theoretically, a right-hand cutter should have right-hand spiral flutes, as the teeth then have positive rake. Although the right-hand flutes tend to pull the cutter out of the socket when used for side-milling, this disadvantage does not outweigh the advantage of having the cutter teeth made with positive rake. It is good practice to hold the cutter firmly in the socket by means of a threaded rod which passes through the spindle and engages the end of the cutter shank, and thus draw the cutter firmly into the spindle socket.

The fact that a left-hand spiral on a right-hand mill tends to push the cutter firmly into the socket is often considered a greater advantage than the positive rake of the right-hand spiral on a right-hand cutter. This applies only when the cutter is used for milling slots where a considerable number of teeth along the body of the mill are engaged. If the mill is used as an end cutter only, then the teeth on the right-hand cutter should be right-handed in order to have a positive front rake. Some manufac-

turers of milling cutters prefer, for ordinary use, end-mills having straight teeth.

Energy Conservation. See Conservation of Energy.

Energy in Chemistry. The chemical combination of two or more elements could not be effected if there were in the universe nothing but matter. The combination of equal parts of hydrogen and chlorine is merely a mechanical mixture until it is exposed to light, and a combination of copper filings and sulphur is only a mechanical mixture until it is exposed to heat. In each case, however, an entirely different substance is obtained. This shows that there is present in the universe a power to perform work, called *energy*. It may manifest itself in the form of light, heat, electricity, etc. It may be changed from one form to another, but, like matter, it cannot be destroyed. In chemistry, energy effects changes in the composition of a substance, or in chemical changes.

Energy in Mechanics. A body is said to possess *energy*, in a mechanical sense, when it has the capacity of doing work—that is, of overcoming a resistance through a distance. In general, energy is something that is given to a body by doing work upon it, as when a weight is raised or is given a rapid motion, or when a spring is compressed; the energy, in turn, is given out when the body itself performs work. Energy is, therefore, sometimes defined as stored work. It is expressed in foot-pounds, the same unit that is used to express work. Energy is either potential or kinetic.

Potential Energy: Potential energy is the power of doing work possessed by a body in virtue of its position or condition. A compressed spring, a raised pile driver, a pendulum at the end of its stroke, and a head of water have the capacity of doing work and are therefore stored with potential energy.

Kinetic Energy: Kinetic energy is the power of doing work possessed by a body on account of its motion. A moving railroad train, a flywheel, a current of air driving a windmill, a falling body, all possess kinetic energy. The kinetic energy of a body is obtained by multiplying one-half its mass by the square of its velocity in feet per second.

Engine. According to modern usage, the word "engine" is generally assumed to mean some type of prime mover, such as a steam engine or internal combustion engine. (See type such as Steam Engine, Diesel Engine, etc.) In the early stages of mechanical developments particularly, almost every mechanical device, especially if intended for the transmission of energy, was called an engine, and this broader usage of the term has survived in a few instances, as for example, engine lathe, dividing engine, dental engine, etc.

Engineering. The field of work wherein scientific knowledge is applied to industrial problems has become known as the "field of engineering." Originally the term engineering was used to designate the design, construction, and operation of industrial works, but it has been extended to cover practically everything in the way of industrial work, including the problems of humanity so far as they are affected by modern industrial methods.

Engineer's Chain. The engineer's chain used in surveying has 100 links, each 1 foot long, making the total length of the chain 100 feet. Every tenth link is provided with a brass tag marked to indicate the number of the links from the end, and the middle of the chain is marked with a round tag. Each end-link is provided with a handle, and the zero point or end of the chain is at the outside edge of the handle. Measurements made with the chain are liable to be inaccurate unless care is taken, because of sagging at the center due to its weight, and also to changes in length caused by wearing at the joints. The length of the chain is adjustable by means of a screw and nut in one of the handles, permitting the length of the end link to be changed. This corrects the error in the total length of the chain, but as the correction is made at one end only, the error is still present in the remainder of the chain. Owing to the wear and other disadvantages of measuring chains, they are gradually being displaced by heavy steel tapes. The metric chain has 100 links, each 20 centimeters long, the total length of the chain being 20 meters. See also Gunter's Chain.

Engine Lathe. A name commonly applied to a general-purpose metal-working lathe of the hand-manipulated type found in practically all machine shops. Such lathes are called *engine* lathes because during the early stages of lathe development, the term engine was applied quite generally to different classes of mechanism. See Lathe Classification.

Engines, Passenger Automobile. A review of specification data for 38 types and sizes of American engines built by 8 companies for passenger automobiles shows that maximum brake horsepower for six-cylinder engines ranges from 78 to 120 H.P. with a majority in the range from 85 to 100 H.P. For eight-cylinder cars maximum brake horsepower ranged from 60 to 160 H.P. with a majority in the range from 105 to 140. Most of the horsepower ratings were given for rotational speeds in the range of 3400 to 3700 R.P.M., although a few were rated at 3800 and 4000 R.P.M. In the 6-cylinder engines piston diameters ranged from 3 to 3½ inches with the majority in the range from 3¼ to 3 7/16 inches. The length of piston strokes in 6-cylinder engines ranged from 3¾ to 5 inches with the majority within the range from 4⅛ to 4⅜ inches. In the 8-cylinder engines piston diam-

eters ranged from 2.6 to 3½ inches with the majority in the range from 3¼ to 3½ inches. Piston strokes ranged from 3.2 to 4⅞ inches with the majority in the range 4¼ to 4½ inches.

English Gear-Bronze. This is an alloy composed of 88.7 per cent of copper, 11 per cent of tin, and 0.3 per cent of phosphorus. The phosphorus is introduced into the alloy in the form of phosphor-copper containing 15 per cent of phosphorus, so that the working formula for the preparation of the alloy is: Copper, 87 per cent; tin, 11 per cent; phosphor-copper, 2 per cent. When properly made, this bronze will have an ultimate strength of 48,000 pounds per square inch, a yield point of 26,000 pounds per square inch; a specific gravity of 8.83; and a Brinell hardness number of 82. The elongation is from 17 to 18 per cent in two inches, and the reduction of area, 18 per cent.

English Legal Standard Wire Gage. This gage is used in England for all wire. It is also known as the Imperial Wire Gage, and Standard Wire Gage.

Engraving Machines. Engraving machines are designed to reproduce the form of a pattern or model on the part to be engraved, by means of a mechanism which transmits the movement of a tracing point to a suitable cutting tool. In the operation of the machine, the tracing point is made to follow the pattern or model, usually by guiding it with the hand. There are two general types of engraving machines. On one type the tool does not revolve, but is drawn across the work so that it operates the same as a planing tool. The angular position of the graver or tool may be varied to secure different effects, and the tool-holder may also be turned on some machines so that the graver will be kept facing the changing direction of the cut, but the tool does not revolve continuously. Engraving machines of this type are extensively used by jewelers, etc., for engraving letters on silverware, name-plates, ornamental designs, and for similar operations. Engraving machines of the second class or type mentioned are equipped with rotating cutters. They are adapted more especially to the engraving of dies, steel stamps, etc., and, in some cases, for special manufacturing operations.

Engraving machines may be further classified according to the form of mechanism utilized for reproducing the pattern or model on the engraved part. Many of the types intended more particularly for engraving letters or ornate designs on nameplates, dies, silverware, etc., have a pantograph mechanism for reproducing the pattern or model on a reduced scale. Other machines of the reducing type, or those using a model that is considerably larger than the design or form to be engraved, are so arranged that the necessary reduction between the movement of the tracing

point which bears against the pattern, and the tool or cutter is obtained by simply attaching the tracer and cutter head to a lever at distances from the pivot of the lever proportional to the reduction required between the pattern and engraved part. There is still another type of engraving machine which does not have a reducing mechanism, but which operates direct, in that the tracing point bears against a model corresponding in size to the impression or surface to be engraved, and this tracing point guides the cutting tool by a direct connection with the cutter spindle or the member in which it is mounted.

Entropy. In thermodynamics, especially in dealing with steam, the change in entropy or in the "condition" of the water or steam is frequently referred to. The change in entropy, which results when the required amount of heat to raise one pound of water from 32 degrees F. to the boiling point (212 degrees F.) is added, is called the "entropy of the water"; the change in entropy during evaporation, that is, the heat of evaporation divided by the absolute temperature of the boiling point, is called the "entropy of evaporation"; and the entropy of the water plus the entropy of evaporation is called the "entropy of steam." The entropy of water is approximately equal to the quotient of the heat added to one pound of water to raise its temperature from 32 degrees F. to 212 degrees F., divided by the average of these two temperatures above absolute zero.

Epicassit. Epicassit is a material which is used for coating iron or steel to protect the metal against corrosion. Epicassit consists of pure tin or of lead and tin in various proportions; an alloy of lead, tin, and zinc is also used with satisfactory results. The metal alloys are reduced to a powdered condition, and this powder is mixed with so-called *epicassit fluid* to a consistency of a thick creamy paint, which is applied with a thick bristle brush, and then melted on the surface to be coated by heating the article. Any clean source of heat may be employed for the amalgamation, such as a blow-torch or a clean fire, or an oven. In making local repairs of vats, tanks, etc., or in entirely recoating worn surfaces, epicassit is particularly useful, as it avoids the necessity of dismantling the equipment, shipping it to the dipping plant, and then remounting it.

Epicyclic Gearing. An epicyclic or planetary gear train consists of a number of meshing gears, of which at least one revolves around a central gear, at the same time rotating about its own axis, so that the arm or bracket supporting such planetary gear, or gears, is given a definite speed of rotation by the driving gears. When the arm or bracket is the driving member of the combination, it imparts a definite speed to the driven gear, any intermediate gears or pinions simply acting as members for the

transmission of motion between the principal parts—the driving and driven members of the combination. The arrangement offers possibilities of securing high speed ratios with comparatively few gears, compactly arranged. It lends itself to many transmission problems that would otherwise be solved with difficulty and require cumbersome gearing. Adaptable and convenient as are epicyclic trains, their use has been largely limited to certain types of speed reducers, and special, intricate machines or mechanisms.

If F = size of fixed gear, P = size of planet gear, and R = rotation of planet gear about its axis, per revolution of driving arm, then

$$\text{For spur gears } R = 1 + \frac{F}{P} \quad \text{.........} (1)$$

$$\text{For internal gears } R = 1 - \frac{F}{P} \quad \text{.........} (2)$$

In formula (1), one turn is added due to the bodily rotation of the planet gear about the fixed gear. In formula (2), one turn is subtracted due to the opposite rotations of the planet gear and driving link. If the fixed and planet gears are a beveled form, with axes at 90 degrees, the rotation of the planet gear will depend entirely upon the relative sizes of the fixed and planet gears.

Epicycloid. An epicycloid is a curve traced or described by a point located on the circumference of a circle which rolls on the outside of the circumference of another circle. If the moving circle rolls on the inside of the periphery of another circle, a point on the circumference will trace or describe a *hypocycloid.* These mathematical curves have mechanical importance, because the teeth in the cycloidal system of gear teeth are formed according to these curves.

Equaling Files. This is a type of file that is made from mill sections and is nearly of blunt form, but has a very slight curvature extending from the point to the tang. These files are double-cut and mostly bastard. Equaling files are used for general shop work, but are seldom employed except for fine toolmaking.

Equalizing Dog. In using a double-ended dog, care should be taken to adjust the driving pins so that there will be an equal pressure on each side. To avoid careless adjustment of the driving pins, what is known as an "equalizing dog" is sometimes used. This merely consists of two V-shaped clamps held together by bolts on opposite sides of the work and having extension driving ends. By adjusting the clamping bolts, the ends are brought firmly into contact with the driving pins. A convenient method

of equalizing the pressure on the pins, when a double-ended dog is used, is by means of an auxiliary plate into which the driving pins are inserted. This plate is attached to the front of the regular faceplate by means of bolts or studs which are screwed solidly into the regular faceplate but fit loosely into slots of the driving plate. These slots are radial and in line so that if one driving pin is subjected to greater pressure, when first starting a cut, this excess pressure causes the driving plate to shift so that the pin of the opposite side is automatically adjusted.

Equalizing Sets. Flywheel motor-generator equalizing sets perform the function of equalizing the load on a generating plant by taking care of the high peaks caused by fluctuating loads, such as mine hoists, etc. They usually consist of an induction motor and one or two direct-current generators with an accurately balanced cast-steel flywheel swung between them, and one or two direct-connected exciters overhung at the ends of the set. The wheel is used to store the energy when the load is light, returning it to the system when the peaks come on. The induction motor is of the phase-wound collector-ring type with a regulator in the secondary circuit so arranged that, when the supply of current to the motor increases to more than a predetermined amount, resistance is automatically inserted in the secondary motor circuit, which has the effect of limiting the current taken by the motor, and thus allowing the excess energy to be supplied by the flywheel.

Equations. An equation is a statement of equality between two expressions; thus, $5x = 105$ is an equation. Equations are used for the solution of mathematical problems. An equation is said to be of the *first degree* if it contains the unknown in the first power only. For example, $3x = 9$ is an equation of the first degree, because the unknown quantity x is in the first power. An equation which contains the unknown quantity in the second, or first and second, but no higher power, is called a *quadratic equation.* Thus, $x^2 + 3x = 18$ is a quadratic equation. An equation which contains the unknown quantity in the third power is called a *cubic equation.* Thus, $x^3 + 3x^2 + x = 22$ is a cubic equation. The solving of equations involves algebraical operations. See also Chemical Equation.

Erg. The erg is the *unit of work* in the centimetergram-second (C.G.S.) system, also frequently known as the *absolute* system of measurement. An erg equals one dyne-centimeter, the dyne being the unit of force in the C.G.S. system, and being equal to 1/981 gram. The unit of power is derived from the erg, the unit of power being one watt, which is equal to 10,000,000 ergs per second.

Erichsen Value. The term "Erichsen value" as applied to sheet metal is a factor used to indicate the workability of sheet metal. The test is conducted by supporting the sheet on a circular ring and deforming it at the center of the ring by using a spherical shaped tool. The depth of the impression or cup, in millimeters, required to obtain fracture is the Erichsen value of the metal. Erichsen standard values of sheet metals are furnished by some manufacturers for various sheet thicknesses. See Sheet-metal Testing.

Escapements. An escapement may be considered as a form of ratchet mechanism having an oscillating double-ended pawl for controlling the motion of the ratchet wheel by engaging successive teeth. Escapements are designed to allow intermittent motion to occur at regular intervals of time. As applied to a pendulum clock the escapement serves two purposes, in that it governs the movement of the scape wheel for each swing of the pendulum and also gives the pendulum an impulse each time a tooth of the scape wheel is released. An escapement should be so arranged that the pendulum will receive an impulse for a short period at the lowest part of its swing and then be left free until the next impulse occurs. One of the earlier forms of escapements was known as the "anchor" or "recoil" escapement. With this type, the pendulum was never free, but was controlled by the escapement throughout the swing. To avoid this effect, the Graham "dead-beat" escapement was designed and has been extensively used. When the escapement is in action, the pallets (two ends of the double-ended pawl) alternately engage the teeth of the scape wheel, which revolves intermittently. In designing an escapement of this type, the pallets are so located as to embrace about one-third of the circumference of the scape wheel. One of the features of the dead-beat escapement is the effect which friction has on its operation. During each swing of the pendulum, there is a rubbing action between the points of the scape wheel teeth and the surfaces of the pallets, so that the pendulum is retarded constantly by a slight amount of friction. This friction, however, instead of being a defect, is a decided advantage, because, if the driving force of the clock is increased so that the impulse on the pallets becomes greater, the velocity of the pendulum tends to increase, but this effect is counteracted by the frictional retardation caused by a greater pressure of the teeth of the scape wheel on the faces of the pallet.

Etching. A common method of etching names or simple designs upon steel is to apply a thin, even coating of beeswax, or some similar substance which will resist acid; then mark the required lines or letters in the wax with a sharp-pointed scriber, thus exposing the steel (where the wax has been removed by the

scriber point) to the action of an acid, which is finally applied. The proper application of the ground which is used to protect the parts from the action of the corroding fluid is very important. For general purposes, beeswax of the proper consistency is excellent, and it can be applied easily in any desired thickness. Before applying the wax, it is important that the surface be thoroughly clean and absolutely dry, and the difference in temperature between the wax and the article to be etched should be slight. If it is necessary to dip the piece into melted wax, the article should be kept immersed for a few moments until it acquires the same temperature as the molten wax. If there is a film of oil on the surface to be coated, the wax will cover it but not adhere, and in consequence the etching fluid will run under the wax and produce a smear or blur. The same effect is produced by moisture, except that in this case the blur is likely to be worse, as there is an affinity between water and etching fluid which causes spreading.

Etching Acids. The following fluids have been tried on the various substances for etching and found to work satisfactorily: *Iron and Steel:* Hydrochloric acid (full strength). *Brass:* Nitric acid. *Copper:* A mixture containing 2 parts of nitric acid and 1 part sulphuric acid. *Silver:* Nitric acid, 3 parts, water, 1 part. *Gold:* A mixture containing 1 part of nitric acid and 3 parts of hydrochloric acid. This mixture should be prepared just before being applied and should be used warm, under a hood or fume closet. *Platinum:* The same mixture as that used for gold. *Lead:* Nitric acid. *Aluminum:* A 10 per cent solution of caustic soda or potash. *Zinc:* A mixture containing equal parts of hydrochloric acid and water, used warm. *Glass:* Hydrofluoric acid. The article may be immersed in the liquid acid for a few minutes or it may be exposed to the fumes from five to fifteen minutes. Extreme caution should be used in handling this acid, using rubber gloves for the hands and a lead or hard rubber container for the acid. Contact with the skin will cause severe burns. All of these acids may be used full strength and will act instantly, but if the etching is to be of considerable depth most of them may be diluted with water before applying. This will require more time, but will produce a cleaner cut. The exception to this is the mixture for gold and platinum, which must always be used full strength and applied as warm as the melting point of the wax will permit.

Etching, Electrical. See Electro-etching.

Etching Resists. Various acid-resisting materials are used for covering the surfaces of steel rules, etc., prior to marking off the lines on a graduating machine. When the graduation lines

are fine and very closely spaced, as on machinists' scales which are divided into hundredths or sixty-fourths, it is very important to use a thin resist that will cling to the metal and prevent any under-cutting of the acid; the resist should also enable fine lines to be drawn without tearing or crumbling as the tool passes through it. One resist that has been extensively used is composed of about 50 per cent of asphaltum, 25 per cent of beeswax, and, in addition, a small percentage of Burgundy pitch, black pitch, and turpentine. A thin covering of this resisting material is applied to the clean polished surface to be graduated and, after it is dry, the work is ready for the graduating machine. For some classes of work, paraffin is used for protecting the surface surrounding the graduation lines which are to be etched. The method of application consists in melting the paraffin and raising its temperature high enough so that it will flow freely; then the work on which the graduating is to be done is held at a slight angle and the paraffin is poured on its upper edge. As the melted paraffin flows across the surface of the work, the latter will be covered with a thin protective coating.

Etch Test. The etch test is a method for testing metals by microscopic inspection. The test specimen is ground or polished and then etched by a suitable acid or other etching fluid for a sufficient period to develop the structure of the metal.

Eutectoid Steels. A steel composed wholly of pearlite is called eutectoid, and contains about 0.90 per cent of carbon. Steel with a lower carbon content is called hypo-eutectoid and it consists of pearlite and "free" or "excess" ferrite, the amounts depending upon the carbon content. Steel containing more than about 0.90 per cent is called hyper-eutectoid and it consists of pearlite and free cementite. Eutectoid steel is also known as saturated steel.

Evaporation Rate. See Rate of Evaporation.

Ewart Chain. Same as Link-belt.

Exciters. Almost all synchronous machines are dependent on an external source of direct current for the magnetization of their fields, and the machines furnishing this excitation are generally termed *exciters*. The exciters may be either direct connected to the main generators or driven separately by prime movers or motors.

Exhaust System. The term "exhaust system" as applied to certain types of low-pressure industrial pneumatic systems is not accurately defined but usually is interpreted as including dust collecting, fume removal and low-pressure conveying systems. Heating, ventilating and air conditioning systems are definitely

excluded. A general characteristic of exhaust systems is that the fluid flowing through the piping is not homogeneous. It is a mixture, usually of air as the parent fluid, carrying solids in suspension or vaporous or gaseous materials. Broadly, an exhaust system is a pneumatic conveying system even though its primary purpose may be quite different from the mere transportation of materials.

Expanded Metal. The term "expanded metal" is applied to sheet metal which has been stretched or expanded to form a screen, by first splitting the solid sheet intermittently so that the entire sheet has a series of closely spaced parallel cuts, to permit expanding it laterally to form open screen work. Thus, as the sheet is stretched edgewise the numerous slits open and the metal between them forms a screen of diagonal pattern. Expanded metal screens are made from stock of various thicknesses and are used for concrete reinforcing, metal laths, machine guard screens, and for various other purposes.

Expanding-Band Clutch. This is a clutch similar to the contracting-band clutch, except that its action depends upon the expansion of a band or ring which, when expanded, grips the inside of a drum surrounding it, and thus transmits power.

Expansion. Practically all substances expand when heated. The expansion of solid bodies in a longitudinal direction is known as the *linear expansion.* The expansion in volume is called the *volumetric expansion;* this latter equals three times the linear expansion.

If the amount that a steel rod lengthens when its temperature is increased one degree F. is known, the expansion for a greater increase of temperature may be determined readily. In engineering handbooks tables will be found which give the linear expansion of different metals and other materials, per unit of length, for an increase in temperature of one degree. This figure which is called the *coefficient of expansion,* is obtained by dividing the amount that a rod of given length expands after a one-degree rise in temperature, by the original length of the rod. For instance, if a rod 120 inches long expanded 0.0008 inch due to a one-degree F. rise in temperature, the coefficient of the linear expansion, or linear expansion per unit of length per degree F., would equal $0.0008 \div 120 = 0.00000666$. Therefore, a rod made of this particular material would increase 0.00000666 of its length for each rise in temperature of one degree F. Hence, the total amount of linear expansion may be determined by the following rule:

Rule: Multiply the length of the rod or other part by the coefficient of expansion for that particular metal, and multiply the

product by the difference between the original temperature and the temperature after heating.

Expansion, Adiabatic. See Adiabatic Expansion and Compression.

Expansion Arbor. This is a type of arbor the diameter of which can be decreased or increased within certain limits. Its diameter may be varied to fit varying diameter holes in parts to be machined, thereby reducing the number of arbors required for a given range of work. Many different designs of expansion arbors are found in machine shops.

Expansion Bends. For low-pressure steam and exhaust mains, expansion joints of any suitable standard make may be used to take up or relieve the strains on a piping system, but for high-pressure steam mains, it is customary and advisable to use expansion pipe bends made up of full-weight or extra-heavy steel or wrought-iron pipe. When the steam main is of considerable length, it is advisable to divide the expansion between different sections of the piping system, anchor the main rigidly at a point near the middle of each section, and provide an expansion bend in each section. The amount of expansion that can be taken care of by an expansion bend of wrought-iron or steel pipe depends upon the shape of the bend, the mean radius of the bend, the outside diameter of the pipe from which the bend is made, and the amount of straight pipe allowed between the arcs or curved portions of the bend.

Expansion Bolt. An expansion bolt is so designed that it can be expanded in a hole in which it is inserted. The expansion may be produced by a screw which enters and expands a split sleeve. Such bolts frequently are used for holding parts to brick, stone, or concrete floors or walls. The expansion part of the bolt enters the hole in the brick, stone or concrete and is then expanded, thus holding the bolt firmly. Expansion bolts are intended especially for "blind holes" in materials which require plain or untapped holes.

Expansion Fits. The term "shrink" or "shrinkage" fit commonly is used when a ring-shaped outer member is heated and expanded in order to obtain a very tight fit between the outer and inner parts as the outer member shrinks around the hub or inner member. For some classes of work this process is reversed—that is, the inner part is *contracted* by using dry ice to lower its temperature; then a tight fit is obtained as the inner part expands in the outer member. The temperature of dry ice is about 109 degrees F. below zero; consequently, it may be used for contracting metal parts before inserting them into the holes or recesses. For example, this method has been applied in assembling cast-iron

sleeves or liners into engine cylinder block castings. The liners are ground to a diameter that will provide a tight fit when they expand into the cylinder bores. They are placed in a dry ice refrigerator for 16 minutes, during which time they shrink about 0.006 inch in diameter. They are then inserted quickly into the cylinder bores and soon expand to provide a tight fit.

To cite another example, dry ice has been used in assembling alloy valve seat rings into cylinder blocks. The rings remain in the dry ice refrigerator from 6 to 12 minutes and attain a temperature of at least 90 degrees F. below zero. The resulting shrinkage makes it possible to insert them readily into the recessed holes of the cylinder block. See Shrinkage Fits; Forced Fits, Driving Fits.

Expansion, Isothermal. See Isothermal Expansion and Compression.

Expansion Joints. In the design of a system of piping, either for power or heating, allowance must be made for the strains due to expansion and contraction. This expansion usually amounts to about 1½ inches per 100 feet of pipe. The expansion and contraction is provided for by the arrangement of the piping, in most cases, but, for long straight pipe lines, expansion joints must be provided. There are three methods commonly used for taking up the expansion in pipes: 1. By using so-called sweep or expansion bends in place of cast-iron elbows, and arranging the piping so as to provide the maximum amount of flexibility or spring. 2. By the use of swing or swivel joints. 3. By the use of expansion or slip joints.

Expansion Ratio. See Ratio of Expansion.

Explosive Engraving. Explosive engraving is being used to accurately reproduce designs on metal surfaces. This can be accomplished by means of a shaped charge or a stencil. In the shaped charge method, a bas-relief is carved at one end of a slab of explosive and this face is put in contact with a metal plate. Detonation of the explosive transfers the design onto the plate.

In the other method of engraving, a stencil bearing the required design is interposed between a plane surface of explosive and a metal plate. The explosive force is transmitted better through the open parts of the stencil than through the solid part, thus producing the required design.

Explosive Forming. Explosive forming takes advantage of the sudden high-velocity release of the powerful energy of explosives. The rapidly applied, almost instantaneous, shock-waves

and gas pressures of brief duration caused by the detonation of explosive charges or the burning of propellant powders are of sufficient magnitude to permanently deform the metal upon which they act. The metal is moved through the elastic into the plastic range and takes a permanent set in thousandths—and in some cases a few millionths—of a second. The process has been applied in the aircraft industry to shape the ultra-high-strength temperature-resistant materials used in aircraft and missile construction.

An explosive charge can be considered as a compact, economical, source of tremendous energy, capable of doing large amounts of work. When an explosive charge is detonated in intimate contact with a steel surface, pressures of approximately four million psi can be developed at the surface, depending on the type of explosive and the properties of the metal. Lower pressures can be obtained by placing the explosive charge at some distance from the workpiece and using an energy transmittal medium such as air or water between them. In such cases the magnitude of the pressure on the part—which can vary from several thousand to several hundred thousand psi—depends on the type, amount, and shape of explosive, the distance from the charge to the work, the type of pressure-transmitting medium used, and the effects of confinement of the pressure produced by the detonation.

Explosive forming may be accomplished by a shock wave, gas pressure, or a combination of the two, depending on the shape of the cavity in which the explosive charge is fired. Essentially, there are two distinct methods of explosive forming: pressure-forming with "low-energy" explosives (deflagrating or propellant type explosives)and shock-forming with "high energy" explosives (detonating explosives). Pressure forming must be done in a closed system, due to the confinement required to make the propellant burn and to effectively use the pressure generated by the burning propellant. Shock forming can be done in closed systems but it is generally performed in open- and semi-open systems—particularly for forming large-size parts. Pressure can be applied directly through a medium such as water or oil, or by way of a piston. If the workpiece is to reach the bottom of the die, air should be evacuated from between the workpiece and the die forming surfaces before forming to prevent surface damage of the workpiece due to the temperature rise associated with air entrapment.

Gas pressure and rate of deformation can be controlled by carefully selecting the amount and type of explosive mixture or propellant, the size of the container, and the type of pressure-transfer medium. With low-energy explosives, such as propellants or black powder, the pressure can be built up slowly at

first, increasing to a peak at the end, or the peak pressure can be at the beginning or any point during the cycle. Time can be controlled from milli-seconds to several hundredths of a second. With high energy explosives, peak pressures are invariably obtained near the beginning of the cycle. Time of control is usually in micro-seconds, although total duration of the load may extend to milli-seconds.

Explosive Hardening. Closely controlled forces from sheet explosive are being used to surface harden and improve the wear resistance of castings made from manganese steel. In this method—also called velocity-impact hardening (VIH)—shock waves from the explosion transform the soft, ductile, austenitic steel by stressing it internally. Since the sheet explosive can be hand-formed to any required contour, cut to desired length, and glued to the specified section of the part, localized hardening can be performed to strengthen critical sections. While many parts can be explosively hardened without distortion, some may require straightening after hardening. Explosive stresses should be compressive, if possible, to avoid setting up residual stresses and tension which might rupture the part. For deeper hardening, the sheet explosive can be stacked in layers, and for shallower hardening, a modifying material can be sandwiched between the part and the explosive. Multiple shots can be used to increase the surface hardness without affecting the depth of hardness.

Explosive Rivets. Explosive rivets are set into metal by means of a special riveting iron which heats the rivet head to about 300 degrees F. and causes detonation of an explosive charge (usually lead azide-tetrazene) in a cavity in the rivet shank. The explosion causes the shank to expand, forming a tight joint between two or more parts.

Explosives. An explosive is a substance or mixture of substances, which is likely on the application of heat, pressure or a mechanical blow to a small portion of the mass, to be converted in a very short interval of time into other more stable substances, largely or entirely gaseous. The gaseous products generated are at high pressure and temperature, and capable of doing mechanical work on expansion. Both the velocity and shape of the wave produced are critical. There are two basic types —low- and high-energy explosives.

Low-energy explosives (or deflagrating explosives) are propellants which contain all the oxygen needed for their combustion, and which burn rapidly rather than explode—thus producing gas which expands and applies pressure. These explosives include the various powders (black, smokeless and ball)

used for ammunition, and are obtainable in low burning rates which vary from extremely slow blasting powder to high-velocity smokeless pistol powders. They may be used in blank cartridges, shotgun shells, or any other confining container that will permit firing.

High-energy explosives (or detonating explosives) function by instantaneous decomposition rather than by burning, and are characterized by very high rates of reaction and high pressure. They are detonated by the shock of a primary explosive, expand much more rapidly than low-energy explosives, and create considerably more shock per unit of weight.

An explosive may consist of a single chemical compound (like mercury fulminate) or it may be a mixture of a combustible material and an oxidizing agent. Two types of high-energy explosives are based on either nitroglycerine or trinitrotoluene (TNT). Ammonium nitrate is sometimes used as an oxygen supplier and gas-producing base. On detonation, an exothermic chemical reaction takes place. The energy released per gram of explosive is about 1000 calories—the exact value depending on the particular explosive.

Exponent. In mathematics, an exponent is the figure or symbol which indicates the power to which the quantity to which it is affixed is to be raised. In the expression 5^3, the exponent or small figure (^{3}) indicates that 5 is to be raised to the third power; the expression A^n indicates that A is to be raised to the nth power, n being the exponent.

Extensometer. The extensometer is an instrument which may be used in making very careful measurements of elongation, as in determining the elastic limit of materials. With such an instrument it is easy to determine when the load and elongation cease to be proportional. Shortly after this point is reached, the instrument is removed to prevent injury when the specimen breaks.

Extractors, Oil. See Chip and Oil Separators.

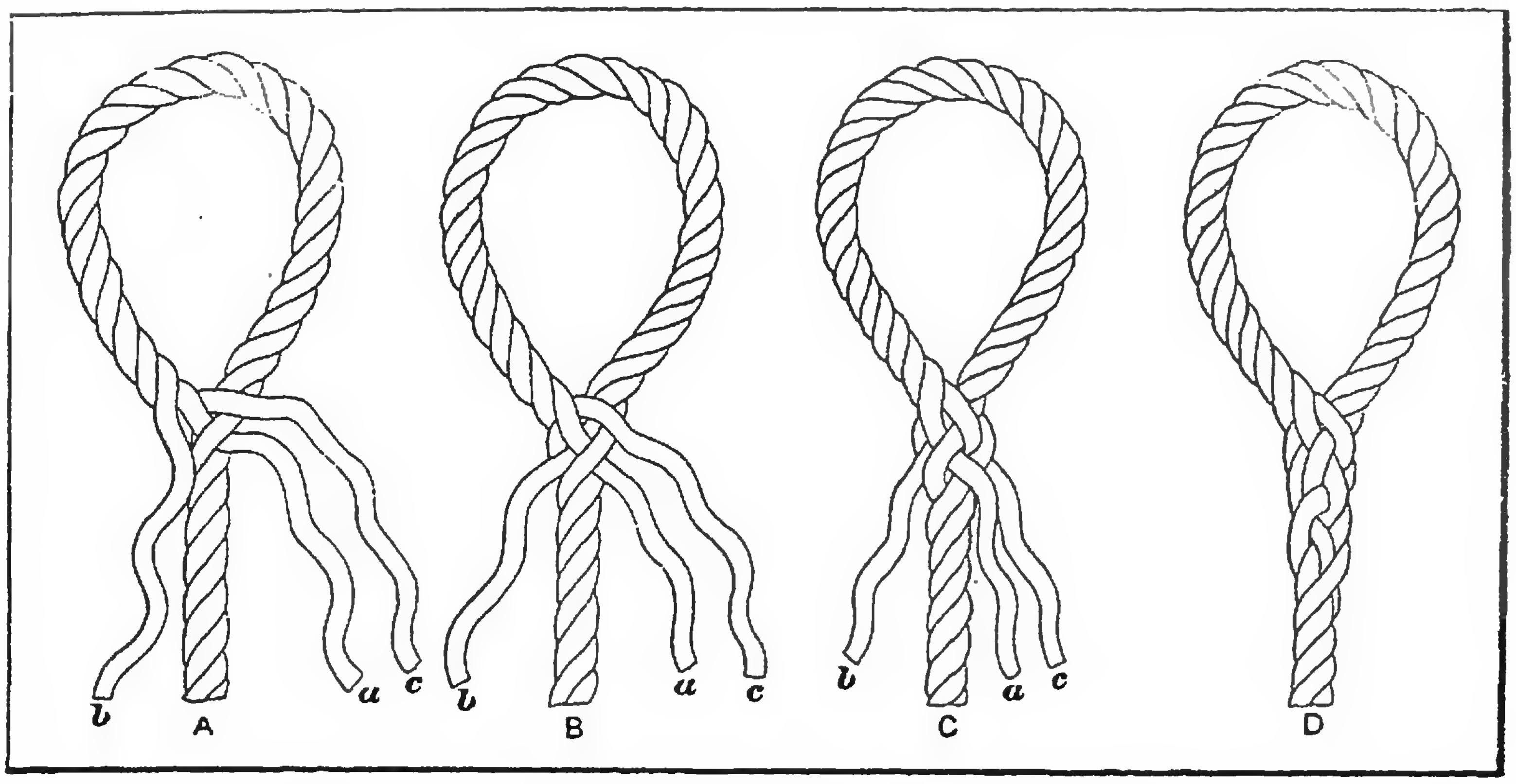
"Extra Heavy." When applied to pipe, the term "extra heavy" means pipe thicker than standard pipe; when applied to valves and fittings, the term indicates goods suitable for a working pressure of 250 pounds per square inch. See also Pipe Schedule Numbers.

Extrusion of Metals. The extrusion process is a method by means of which shapes of fairly plastic metals are produced by forcing the metal, which is usually heated, under high pressure through an aperture of the shape to be produced. In this manner, a continuous bar or pipe of the cross-section of the aperture

or die is produced. Lead and tin can be extruded at comparatively low temperatures (250 degrees F.), while copper requires a temperature of about 1750 degrees F. The advantages of the extrusion process are that it permits parts of unusual cross-section to be produced cheaply. On account of the high pressure under which the metal is extruded, its structure becomes more compact and its strength is increased. The surfaces are smooth and free from flaws and other defects. Sometimes metals are extruded at atmospheric temperatures, in which case a higher pressure must be used, but the metal will be more condensed and the grain refined, adding to its strength, hardness, and toughness. It requires, however, five times the pressure to extrude aluminum at 70 degrees F., as compared with the pressure required at 600 degrees F. Small gears, ratchet wheels, racks, padlocks hasps, and other special shapes are extruded in long bars which are afterwards sawed up to give the pieces their required thickness. The extrusion process is used extensively for making collapsible tubes of tin and lead, for containing dentifrice, artists' colors and other preparations. In the extrusion of metals it is natural that lead should have been the one first used, as this is the most plastic of metals. The other metals extruded are aluminum, zinc, copper, steel, and brass, as well as various other alloys. See Chipless Machining, and Cold Extrusion.

Eyebolt. This is a bolt threaded at one end and provided with a loop or eye at the other, so that it may be attached to a ring or hook.

Eye-Splice. When a loop is formed at the end of a rope by splicing the free end to the main or standing part of the rope, this is known as an *eye-splice*. The end of the rope is first unlaid about as far as it would be for making a short splice. After bending the end around to form a loop of the required size, the middle strand *a* (see diagram) is tucked under a strand on the main part of the rope, as illustrated at *A*. The strand *b* is next inserted from the rear side under the strand on the main part which is just above the strand under which *a* was inserted. Since strand *b* is pushed under the strand on the main part from the rear side, it will come out at the point where strand *a* went in, as illustrated at *B*. The third strand *c* is now passed over the strand under which strand *a* was inserted, and then under the next successive one, as illustrated at *C*. These three strands are next pulled taut and then about one-third of the fiber should be cut from them; they are next tucked away by passing a strand over its adjoining one and under the next successive strand. The reason for cutting away part of the fiber or yarns is to reduce the size of the splice and give it a neater appearance. By gradually



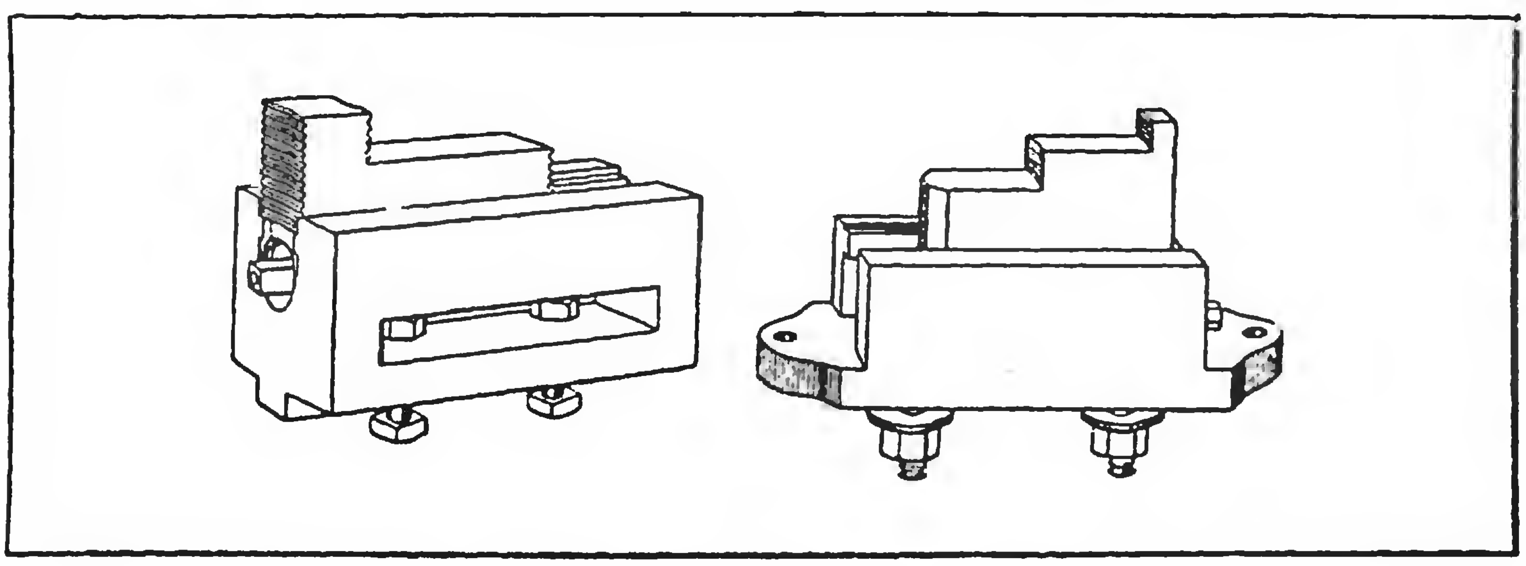
Method of Making an Eye-splice

thinning out the fiber, the over-lapping strands may be given a gradual taper, as indicated at *D*, which shows the completed eye-splice.

F

Face Angle of Bevel Gear. There are two methods of designating the face angle of a bevel gear. According to one method, this is the angle between the top of a tooth and a plane perpendicular to the axis of the gear. The term according to the other method means the angle between the top of a tooth and the axis of the gear or one-half the included angle of the blank.

Face Cam. This is a cam in which a groove for guiding the roller of the cam follower is cut into the flat face of a cylindrical disk. A face cam has an action similar to that of a disk cam, except that the face cam guides the follower positively in both the forward and reverse direction, as the roller engages a slot instead of the periphery of the cam.



Two Designs of Faceplate Jaws

Face Milling. This term as generally used, means the production of a plane surface by the teeth of a milling cutter which operate in a plane that is at right angles to the axis of the cutter.

Faceplate Jaws. Special faceplate jaws (see illustration) may often be used to advantage for holding work on large lathe faceplates, and they are also frequently applied to the tables of vertical boring mills. Three or four of these jaws are bolted to a faceplate or a machine table, as the case may be, thus converting it into a kind of independent chuck. Faceplate jaws are held in position by means of square-headed bolts that engage T-slots in the faceplate or table, and they are additionally held and aligned, in most cases, by a tongue that fits into the T-slot.

Face Width. In spur gearing, the "face" or face width is the length of the teeth or the distance across the gear rim measured parallel to the shaft upon which the gear is mounted. In bevel gearing, the face or face width is the width of the tooth measured on a line parallel to the pitch line.

Facing Materials. Facing materials are applied to the surfaces of foundry molds to improve the appearance of the casting by preventing the fusion of the metal and sand. There are many patent facing materials on the market. Dry plumbago applied with a soft brush is a common facing for green sand work, while a blacking mixture of lead, charcoal, and blacking, mixed with clay water, is extensively used for dry sand and loam molds.

Facing Sand. In molding, the sand that is sifted or riddled over a pattern to form the face of the mold is known as *facing sand.* It may be backed up with coarser floor sand. The facing may be of sifted floor sand or of an entirely different grade.

Factorial. See Permutations or Combinations.

Factoring. In mathematics, factoring is the process of obtaining the factors of a number or quantity; that is, the numbers or quantities which, when multiplied together, will give as a product the given number or quantity. Thus 3 and 11 are factors of 33 because $3 \times 11 = 33$.

Factor of Evaporation. The factor of evaporation is the ratio between the number of heat units required for evaporating one pound of water of a given feed water temperature into steam of a given pressure, to the number of heat units required for evaporating one pound of water from a temperature of 212 degrees F. into steam at atmospheric pressure.

Factor of Safety. It is the practice among most engineers engaged in the designing of machinery to base working stresses for given materials and given classes of work, either upon their own experience or upon the observation or successful experience of others, and so long as the quality of the material remains unchanged, and the service does not vary in character, this method is satisfactory. New conditions, for which precedent is lacking, are, however, constantly arising, and materials of different qualities, either better or cheaper, for which the safe working stresses have not been determined, are introduced. The designer is then compelled to determine the proper stress for the work in hand by using a so-called "factor of safety." The name "factor of safety" is misleading, for several reasons. In the first place, it is not a "factor" from a mathematical point of view, but is, in its use, a divisor, and in its derivation, a product. In order to obtain the safe working stress, the ultimate strength of the material is

divided by the factor of safety, and, in order to obtain this factor of safety, several factors, which, in turn, depend upon the qualities of the material and the conditions of service, are multiplied together. If the ultimate strength of a material like machine steel is 60,000 pounds per square inch and it is subjected to a load of 10,000 pounds per square inch, a factor of safety of 6 is used; that is, the ultimate strength of the material is six times as great as the load to which the material is subjected in service.

Fahrenheit Thermometer. The thermometer that is most commonly used by the English speaking peoples is the *Fahrenheit thermometer* on which the freezing point of water is located at 32 degrees and the boiling point of water (at atmospheric pressure) at 212 degrees. This thermometer scale was probably the first of the three adapted thermometer scales introduced, it having been named after its inventor, a German scientist, who proposed this scale in the early part of the eighteenth century. The Fahrenheit (F.) scale is, as a rule, not used for scientific or electrical work; in that case the centigrade scale is almost exclusively used in all countries.

$$\text{Degrees Centigrade} = \frac{5 \times (\text{degrees F.} - 32)}{9}.$$

Fairbairn Crane. This is a special type of pillar crane supported and pivoted at the foundation only, in which the column and the boom are built in one piece, generally of a box section formed of angles and plates.

Falling Bodies. See Gravity.

Fan Blower. A fan blower is a special form of ordinary ventilating fan adapted commonly for working pressures up to one pound per square inch, although special types may be constructed for higher pressures. The fan blower is employed principally for forges and cupola furnaces.

Fan Brake. A fan brake is a form of absorption dynamometer sometimes used when testing high-speed machinery, such as automobile engines. The fan brake consists of a number of arms keyed to the shaft of the engine, to which flat plates are attached. When such a brake has been properly calibrated, by measuring the power required to revolve it at various speeds, it is very satisfactory. The power absorbed varies as the cube of the speed.

Fans. Fans are used for a number of applications in industrial work. Besides their use for heating and ventilation, they are employed for exhausting dust from polishing and grinding rooms, in which case they are generally connected directly with ducts leading from a hood over the polishing and grinding wheels;

they are also used for exhausting shavings from wood-working machinery, and for many similar purposes in various industries. There are two types of fans in common use: (1) the centrifugal fan, often called a "blower," and (2) the disk fan or propeller.

Farad. The unit of capacity in electricity, as adopted by the International Electrical Congress, in Chicago, 1893, and later made a legal unit for electrical measures in the United States by Act of Congress, July 12, 1894, is the *farad.* This is the capacity of a condenser charged to a potential of one volt by one coulomb of electricity.

Faraday. See under Electrochemical Equivalent.

Fathom. A length measure; 1 fathom = 2 yards = 6 feet = 1.8288 meters.

Fatigue Stresses. So-called "fatigue ruptures" occur in parts that are subjected to continually repeated shocks or stresses of small magnitude. Machine parts that are subjected to continual stresses in varying directions, or to repeated shocks, even if of comparatively small magnitude, may fail ultimately if designed, from a mere knowledge of the behavior of the material under a steady stress, such as is imposed upon it by ordinary tensile stress testing machines. Examinations of numerous cases of machine parts, broken under actual working conditions, indicate that at least 80 per cent of these ruptures are caused by fatigue stresses. Most fatigue ruptures are caused by bending stresses, and frequently by a revolving bending stress. Hence, to test materials for this class of stress, the tests should be made to stress the material in a manner similar to that in which it will be stressed under actual working conditions.

Fatigue Testing Machine. One make of fatigue testing machine designed to record the number of alternations of stress that may be applied to a steel specimen before destruction is accomplished, consists of a baseplate provided with a housing in which are mounted ball bearings that carry the specimen in a horizontal plane, and another housing with ball bearings and a shaft on which a pulley is mounted to drive the equipment from a motor. There are also two ball bearings which are put on the specimen to carry the weights that apply the load or stress. Hook-bars are attached to the weight bearing housings. All the ball bearings are provided with easily adjustable compensating chucks to fit the specimen, so it is a simple matter to mount the specimen in the machine. A bracket at one end of the machine carries a revolution counter which records the number of revolutions made by the specimen under test up to the time of failure. The specimen is connected to this counter by means of a flat notched bar which

falls out of position when failure occurs and causes the counter to stop. At the same time the broken specimen swings out of contact with the driving shaft.

Faure Plate. This is a type of electrode for lead batteries, also known as "pasted" plate, in which the active material in the form of lead oxides is applied mechanically to a lead body. After this the plate is subjected to an electrochemical forming process which produces lead peroxide in the positive plates and sponge lead in the negative plates.

Feather. See Splines and Serrations.

Featheredge Files. Files of this type taper in cross-section from the center toward each edge. They are of blunt form, double-cut, bastard, second-cut, or smooth. This shape is seldom called for, as the knife file is generally used instead.

Feed-Back The word "feed-back," frequently encountered in the description of automatic machines, means the transmittal of information from the output of a system to the input. To further enlarge on this definition consider a thermostat controlling the output of an air conditioning system. If the thermostat measured the temperature and found it to be below the preset setting then it would send back information to reduce the cooling effect. On the other hand, if the thermostat measured the temperature and found it to be above the preset setting then it would send back information to increase the cooling effect of the system. This transmittal of a measured quantity from the output end back to the input end in order to control it, is called "feed-back."

Feed Mechanisms. The term "feed mechanism" or "feeding mechanism" as applied to machine tools or other classes of manufacturing equipment, usually relates to some form of mechanism (1) for feeding either a cutting tool or the work as in turning, planing, drilling or milling, and generally for providing also means of varying the rate of tool or work movement per revolution or stroke; (2) a mechanism for feeding raw material or parts from some source of supply to the working or operating position. A feed mechanism which is designed to control primarily the rate of tool or work-feeding movement usually consists of a train of gearing with provision for changing the ratio between the driving and driven members. Feed mechanisms of the type for feeding stock or parts are made in a great variety of types and designs, depending upon the nature of the work.

Many machines which operate on large numbers of duplicate parts which are separate or in the form of individual pieces are often equipped with a mechanism for automatically transferring

the parts from a magazine or other retaining device, to the tools that perform the necessary operations. The magazine used in conjunction with mechanisms of this kind is arranged for holding enough parts to supply the machine for a certain period, and it is equipped with a mechanical device for removing the parts separately from the magazine and placing them in the correct position wherever the operations are to be performed. The magazine may be in the form of a hopper, or the supply of parts to be operated upon by the machine may be held in some other way. The transfer of the parts from the hopper or main source of supply to the operating tools may be through a chute or passageway leading directly to the tools, or it may be necessary to convey the parts to the tools by an auxiliary transferring mechanism which acts in unison with the magazine feeding attachment. These automatic feeding mechanisms are usually designed especially for handling a certain product, although some types are capable of application to a limited range of work.

Feed Mechanisms, Power Press. See Power Press Feed Mechanisms.

Feed Rate on Machine Tools. The rate of feed as applied to machine tools in general, usually indicates (1) the movement of a tool per work revolution, (2) the movement of a tool per tool revolution, (3) or the movement of the work per tool revolution.

Rate of Feed in Turning: The term "feed" as applied to a lathe indicates the distance that the tool moves during each revolution of the work. There are two ways of expressing the rate of feed. One is to give the actual tool movement per work revolution in thousandths of an inch. For example, the range of feeds may be given as 0.002 to 0.125 inch. This is the usual method. Another way of indicating a feed range is to give the number of cuts per inch or the number of ridges that would be left by a pointed tool after turning a length of one inch. For example, the feed range might be given as 8 to 400. In connection with turning and other lathe operations, the feed is regulated to suit the kind of material, depth of cut, and in some cases the finish desired.

Rate of Feed in Milling: The feed rate of milling indicates the movement of the work per cutter revolution.

Rate of Feed in Drilling: The rate of feed on drilling machines ordinarily indicates the feeding movement of the drill per drill revolution.

Rate of Feed in Planing: On planers, the rate of feed represents the tool movement per cutting stroke. On shapers, which are also machines of the planing type, the rate of feed represents the work movement per cutting stroke.

Rate of Feed on Gear Hobbers: The feed rate of a gear hobbing machine represents the feeding movement of the hob per revolution of the gear being hobbed.

Feed on Grinding Machines: The traversing movement in grinding is equivalent to the feeding movement on other types of machine tools and represents either the axial movement of the work per work revolution or the traversing movement of the wheel per work revolution, depending upon the design of the machine.

Fellows Stub-Tooth Gears. See Stub-tooth Gears.

Fernico. A metal alloy with a coefficient of expansion that is practically the same as that of glass and which can be fused with glass without setting up stresses either in the glass or in the alloy. The alloy can be machined, forged, punched, drawn, stamped, soldered, copper-brazed, and welded. Used wherever tight joints are required between metal and glass, as in vacuum tubes and other devices in which lead-in wires or conducting parts must pass through gas-tight insulating seals.

Ferrite. If a piece of iron or steel is placed under the microscope, it will be found that the metal is not absolutely homogeneous, but consists of various constituents slightlv different in color and forming a surface similar to that of a granite rock. Just as granite shows distinct crystalline grains of different minerals, so iron or steel consists of a mixture of microscopic particles. When having slowly cooled, for example, if consists of an iron carbide, known as *cementite*, and of *ferrite,* which is pure, or nearly pure, metallic iron. Ferrite is a soft and weak constituent with high electric conductivity, and, in many respects, like copper, except in its color. When carbon is present in iron to any great extent, ferrite is transformed into cementite, which latter constituent is harder than glass and nearly as brittle; hence, if one per cent of carbon is present in the iron, 15 per cent of the soft ferrite is replaced by cementite. This is one of the reasons why even a small addition of carbon in steel changes its mechanical properties to so great a degree. See also Steel, Constituents or Structure.

Ferroalloys. This term is applied to an alloy of iron and some other element or elements (carbon excepted) when such an alloy is to be used as a raw material in the manufacture of ferrous metals. Ferroalloys normally contain an amount of carbon equal to or greater than the carbon content of pig iron, but low-carbon ferroalloys are commercially available. The part played by iron in a ferroalloy is a secondary one; it serves simply as a vehicle for carrying the desired alloying elements.

There are many ferroalloys in common use. Some are used be-

cause of the specific properties which they impart to steel when they are dissolved in the iron base, or when they combine with carbon wholly or in part to form carbides. Others are used because of their beneficial effects in ridding steel of impurities, or in rendering impurities harmless. A third group is used to counteract harmful oxides or gases in the steel. The elements of this latter group do not remain in the steel to any great extent after solidification, but are merely fluxes or scavengers of undesirable impurities. Some ferroalloys fall into more than one of the above groups. Some ferroalloys are made in the blast furnace, some in the electric furnace, and some are made by the thermit process. Those commonly made in the blast furnace are spiegeleisen, ferromanganese, ferrosilicon and ferrophosphorus.

Ferromagnetic. See Magnetic Materials.

Ferromanganese. Ferromanganese is an alloy of manganese and iron, containing generally about 80 per cent of manganese, 15 per cent of iron, and 5 per cent of carbon, with small percentages of silicon and other impurities. Iron-manganese alloys, containing more than 30 per cent manganese are called ferromanganese. Manganese is used as a deoxidizer and desulphurizer in the production of nearly all grades of steel. It reduces the amount of oxygen remaining in the molten steel, and by actively combining with sulphur it removes a principal cause of hot brittleness and imparts to the steel better rolling and forging properties. Manganese also serves as an alloying element in steel, assisting in the production of a fine grain structure and enhancing physical strength and ductility. It is used for this purpose in all grades of steel, whether intended for castings, forgings or rolled products. The most commonly used grade of ferromanganese alloys is termed "Standard Ferromanganese," often referred to as "80 per cent Ferromanganese."

Ferrous Alloys. Ferrous alloys differ from non-ferrous alloys in that they contain iron. Steel and cast iron are outstanding examples of ferrous alloys, whereas in the non-ferrous group there are the various brass, bronze, aluminum and other alloys.

Ferrophosphorus. This is an alloy of iron and phosphorus used for the addition of phosphorus to steel. Two grades of this alloy are made, one having approximately 17 to 19 per cent, and the other 23 to 25 per cent phosphorus. The former is usually produced in the blast furnace and either grade may be produced in the electric furnace.

Ferrosilicon. This is an alloy of iron and silicon used for adding silicon in the manufacture of open-hearth steel. In the basic open-hearth process it is used as a deoxidizer and scavenger prior to the use of more expensive alloys. It is also used to

prevent oxidation while holding the bath of steel for chemical determinations. High-silicon ferroalloys find use in the manufacture of steel sheets or strips in which high magnetic permeability and electrical resistance combined with low-hysteresis are essential. Ferrosilicon is also used extensively in the manufacture of steels in which silicon as an alloying element is desirable. Ferrosilicon is produced in many different grades dependent upon the purpose for whch it is intended. The low silicon grades which start at 10 per cent silicon and ordinarily do not exceed 17 per cent, are generally blast furnace products and are called *silvery pig iron.*

Fiber. This is the general name used for a number of structural components of animal and vegetable tissue utilized in the industries. According to the source of the raw material, there are a number of classes of fiber, such as wood fiber, horn fiber, asbestos fiber, etc. Fiber is used for gearing, for friction wheels, as an electric insulating material. and for various other purposes.

Fiber Bending and Forming. Fiber should always be bent parallel to the grain (the long way of the sheet), because it is difficult to bend fiber across the grain without breaking it. The general practice is to soften the material (more or less) by immersing it in hot or cold water until sufficiently tempered, and then drying it in heated forms under enough pressure to keep the shape desired. The fiber should be left in the heated forms long enough so that it will retain the desired shape after cooling. However, heated forms are not always necessary. If the material can be steamed, instead of immersed, it will require less time to set. Angles can be bent in bending brakes fitted with electric, gas, or steam heat. Special pieces can be formed on a hot plate in cast-iron forms, under pressure of a hand-operated spring plunger. In making up the top and bottom forms, some allowance should be made for the fact that fiber swells slightly when it is soaked or steamed. Tubes can be bent by softening in hot water, filling with sand, and clamping in wooden or metal forms, after which it is necessary to dry them at about 150 degrees F.

Fiber Glass. Glass fibers are produced in two distinct types—staple length and continuous. The former are comparatively short fibers, from 8 to 15 inches long, and approximately 0.00025 inch in diameter. Fabrics made from these short fibers resemble cotton or woolen yarns. The continuous fibers, as their name implies, are produced in continuous lengths, limited only by the size of the spools on which they are wound. Their diameter averages about 0.0002 inch.

In the manufacturing process, the fine glass strands are placed on textile spinning machines, where the yarn is spun in the same

manner as cotton or wool yarn. The yarn for fabrics produced from continuous fibers resembles silk or rayon in appearance. Glass fibers of diameters such as are used in making textiles for electrical insulation have extremely high breaking strength. The strength of individual fibers 0.0002 inch in diameter has been shown to exceed 1,000,000 pounds per square inch. No other textile fiber approaches this strength. Tests also show that woven glass fabric is stronger than other textile fabrics. These fibers are made from ¾-inch glass marbles. One marble makes a fiber 0.0002 inch in diameter 98 miles long. One pound of marbles makes 5000 miles of fiber.

One of the interesting applications of "Fiberglas" is for the insulation of electric motors. A "Fiberglas"-insulated motor is much smaller than one having cotton insulation. In fact, the space occupied by a "Fiberglas" motor is about 45 per cent less than that required for a standard motor. This space saving is an important factor in connection with drives requiring a compact design.

Fiber Punching. Fiber can be easily blanked, pierced, and shaved on ordinary punch presses. For blanking and piercing thin material, the punch should be a neat fit in the die, while for stock ¼ inch thick, a difference of about 0.008 inch will give the best results. When a rough edge is not objectionable, fiber can be blanked out up to ¼ inch thick. When heavier stock is blanked, it is likely to "check in" too far and cause considerable wastage, although some material up to 7/16 inch in thickness can be blanked. Smooth edges can be obtained by forcing blanked or sawed fiber blocks through a hollow shaving cutter of the desired shape. The edges of the cutter should have a slant of about 45 degrees. Sharper angles will often give smoother edges, but the cutter will not last as long. A better finish can be had by using a roughing and a finishing cutter. It is generally necessary to allow from 1/16 to ⅛ inch all around for shaving, according to the shape of the pieces. When trouble is encountered by checking of the stock while blanking or shaving, softening the fiber by heating will often overcome the difficulty. Dies and cutters for fiber can be made without any clearance for ½ inch or more below the cutting edge. The bottom of the die may be counterbored within ½ or ¾ inch of the top to facilitate machining. Such a die will not change its size in grinding and will give better results than a die with clearance to the cutting edge. If the cutting edge of a shaving cutter is mouthed out very slightly with a fine oilstone, the stock will bind slightly in passing through, which will tend to polish the edges smoothly.

Field Switches. Field switches are especially designed to open or change the connections of the field of a motor or gen-

erator. One type, for example, has an auxiliary contact which places a discharge resistance across the field before the switch is opened. Another type called the *field break-up switch,* when opened, separates a field winding into two or more sections, insulated from one another.

File Cleaning. A piece of copper is fairly good for cleaning files but sheet-fiber is much better. A disk of fiber mounted upon an ordinary emery wheel stand is very effective. When the file to be cleaned is held against this revolving disk or fiber it will be cleaned much quicker and better than would be possible by hand or by the copper method. Fiber ¼ inch thick is best suited for this purpose.

File History. One of the earliest implements for filing, to which reference can be found, appears to have been made from the skins of certain fish, and even today in Great Britain old-fashioned wood carvers use the skins of the dog fish to smooth their work. *Bronze files* were in use when this metal was the general material for tools and implements, and there is evidence in the Bible that different shapes of files were in use about three thousand years ago. Several specimens of ancient bronze files are still in existence. One of these, believed to be about 3500 years old, was dug up in Crete. This file has a rounded back, as well as a flat surface, bearing an astonishing resemblance to the half-round file of today. It is about 3⅝ inches long, ⅜ inch wide, and ¼ inch thick.

One of the earliest examples of *iron files* was found on the site of the Swiss lake dwellings, and dates from the time when Europe was the home of a race far more ancient than any of which we have any permanent records. This file has coarse teeth running across the blade at right angles to the sides and has a well developed tang, much like that of modern files. Another ancient iron file forms part of the collection of tools left at Thebes in Egypt by Assyrian invaders. This file is believed to date from about the seventh century B. C. Files have been found on the sites of the old Roman camps in England.

Specific references to files were made by Daimachus, a Greek writer in the time of Alexander the Great, about 300 years B. C. This writer enumerates four kinds of steel, describing their uses. From one kind were made files, augers, chisels, and implements for cutting stone. *Steel files* have been used for several centuries, and in an eighteenth century French encyclopedia there are a number of illustrations of files which differ in few respects from the modern tool. Formerly all files were cut by hand, but now practically all files are machine-cut. Although the machine-cutting of files is a comparatively recent development, the idea of machine-cutting is by no means new. Raoul, a Frenchman, cut files by

machinery in the eighteenth century, and in 1836 a file-cutting machine patented by Captain John Ericsson was used in England. Machine-cut files are made with as many as 180 teeth to the inch, the cuts being scarcely discernible to the eye.

File Shapes. See name of file, such as Cant-file; Circular File; Flat File; Half-round Files; Rotary Files; Round Files, etc.

Files, Types. The following types conform to the simplified practice recommendation of the National Bureau of Standards.

Band-saw, Blunt: Equilaterally triangular in section. Parallel throughout. Corners rounded. For sharpening saws with rounded gullets.

Band-saw, Taper: Same as band-saw, blunt, but tapered on all sides.

Cabinet: Flat on one side, convex on the other. Width tapered. Edges slightly blunted and cut.

Cant-saw: Section is an isosceles triangle, with an obtuse angle between the equal sides. For filing cross-cut saws having M-shaped teeth.

Cross-cut (Great American): Knife-shaped section; that is, thicker at one edge than at the other. Width uniform. Thick edge rounded. Used to file two-man saws having Great American style teeth.

Double-ender: Has no tang. Reversible. Tapered from center to each end.

Flat: Width and thickness uniform from heel to middle of cut, and tapered from middle of cut to point.

Half-round: One side flat, the other convex. Width and thickness tapered.

Hand: Width uniform, thickness tapered.

Hand-finishing: Section of regular hand files. up-cut at a short angle, and over-cut at a very long angle to produce a very smooth finish.

Hand-saw, Blunt: Equilaterally triangular in section. Edges parallel throughout.

Knife: Of knife-shaped section; that is, thicker at one edge than at the other. Width tapered.

Lead-float: Open single-cut type having teeth at proper angle for use on lead.

Mill: Width and thickness tapered.

Mill Blunt: Sides and faces parallel.

Pillar: Width uniform, thickness tapered. In general, the thickness is greater, relative to the width, than in other types.

Planer-knife: Parallel in width and thickness. One half of each side single cut, the other half double cut.

Round: Round in section and tapered.

Special Cross-cut: Sides and face parallel, same as mill blunt.

Square: Square in section. Tapered on all sides.

Taper: Equilaterally triangular in section. Tapered on all sides.

Three-square: Equilaterally triangular in section. Tapered on all sides.

Warding: Width greatly tapered, thickness very slightly tapered.

Wood: Open double-cut type having teeth at proper angle for use on wood.

File Teeth. A *single-cut* file or "float," as the coarser cuts are sometimes called, has single rows of parallel teeth extending across the face at an angle of from 65 to 85 degrees with the axis of the file. This angle depends upon the form of the file and the nature of the work it is intended for. A *double-cut* file has two rows of teeth crossing each other. The angle of the first row is, for general work, from 40 to 45 degrees, and the second row, from 70 to 80 degrees. *Rasp* teeth are round on top and disconnected, being formed by raising, with a punch, small portions of stock from the surface of the blank.

Single- and double-cut files are further classified according to the spacing of the teeth. The names commonly used to designate the different grades of cut are "rough," "coarse," "bastard," "second-cut," "smooth," "dead-smooth," or "super-smooth." "Rough" files are usually single-cut, and the "dead-smooth," double-cut. The other grades are made in both double- and single-cuts. Degrees of coarseness are only comparable when files of the same length are considered, the number of teeth per inch of length decreasing as the length or size of the file increases. Some makers use a series of numbers to designate the cut or coarseness instead of names.

File Teeth, Cutting. There are three general methods of cutting the teeth of files: 1. By hand (using a hammer and chisel). 2. By means of special file-cutting machines of the mechanically-operated chisel type. 3. By etching with a mechanically guided tool. While the hand method is comparatively slow and expensive, skillful workmen are able to produce excellent files, although practically all files now used are cut by machines. These machines have been developed so that they not only enable the work to be done efficiently but produce files which are more accurate and effective than those cut by hand.

The *hand method* to be described has been practiced by the hand file-cutters in Sheffield and Lancashire for a century. The large file blanks are ground, and the smaller ones filed to shape, and slightly greased before cutting. The cutter sits before a

square stake on which the blank is laid with the tang toward him and the two ends held down by two leather loops which are pressed down by the right foot. Cutting is begun at the point and is done by a very short chisel, the edge of which is slightly blunted to indent rather than cut the steel. To cut opposite faces of a file the face first cut is laid upon a plate of pewter; triangular and round files are laid in corresponding grooves in blocks of lead.

A *file-cutting machine* is designed to strike a series of rapid blows with a suitably formed chisel, for producing tooth grooves of any desired depth in a file blank which is fed automatically past the chisel at such a rate as to give the desired spacing of the teeth. The chisel head or hammer of a file-cutting machine weighs, complete, from 8 to 12 pounds, and ordinarily makes from 2000 to 3000 strokes per minutes, although the number of strokes may vary from 500 to 3500 per minute, the speed of cutting depending upon the weight of the file being cut. The first known record of a file-cutting machine is a design made by Leonardo da Vinci, the well-known Italian genius, about 1500.

Large quantities of files are not cut by means of a mechanically-operated chisel but by a grooving process that is known as *etching*. This process is entirely different from that of cutting by means of a chisel and produces a higher grade of file. When forming the teeth by etching, the file is laid in a holder where it is steadied and guided by the workman's left hand. With his right hand he operates the etching tool, which is attached to a swinging framework. The etching tool is simply swept back and forth across the work at the proper angle and with the proper degree of pressure, the latter being controlled by the foot of the operator which bears down upon a stirrup which hangs from the handle of the etching tool. This pressure must be varied to suit conditions, such as hard spots in the blanks or the necessity of cutting deeper at one point than at another. The shape of the file is what determines whether a blank should be etched or cut with a chisel. A flat surface should not be etched nor is there any need for it. On round surfaces, however, particularly where it is necessary to preserve accurately the outline of the blank, etching is preferable to cutting. A satisfactory machine has been developed for etching the first teeth of a double-cut file.

File Teeth, Resharpening. There are several processes for resharpening files by the use of acid solutions. The acid must not be permitted to attack the files unduly. To prevent this, it is advisable to make a few tests or trials to determine the length of time the files should be immersed in order to obtain the desired results, before proceeding with the work on a quantity basis.

Cleaning Solution: First clean the files by immersing them in a solution of caustic coda and boiling water for a period of from

ten to fifteen minutes. This solution is made by dissolving 100 grains of caustic soda in one gallon of water. The same proportions should be used if a larger quantity of the solution is required. Two gallons will ordinarily be sufficient for cleaning 100 files of the sizes generally employed in the shop.

Use of Nitric and Sulphuric Acids: After the cleansing treatment, the files are placed in an acid bath. This bath is made by adding twelve parts of water (by volume) to a solution consisting of one part nitric acid, one part fuming (Nordhausen) sulphuric acid, and one-third part concentrated sulphuric acid. These parts are measured by volume and not by weight. The files, when placed in the acid solution, should not overlap and should be arranged so that the solution will reach all surfaces. It is preferable first to suspend the files in the tank and then add the acid solution. The files should be allowed to remain in the solution from five to ten minutes, the exact time being determined by experiment.

Sulphuric-acid Process: Experience in sharpening between 2000 and 3000 files in acid solutions indicates that the following method gives good results. The first step is to remove all grease and dirt from the files. This may be done by soaking the files a few hours in gasoline and then brushing them with a wire brush, or by boiling them a few minutes in a 10 or 15 per cent water solution of caustic soda, and then drying and brushing them. It is essential that the files be thoroughly cleaned, as the acid cannot reach the steel through grease or oil. The clean files are placed in an enamel basin, a lead-lined box, or a "Pyrex" glass baking dish. Short pieces of wire or nails are placed between the files to separate them sufficiently to permit the acid to reach all the surfaces that are to be sharpened.

After covering the files with water, sulphuric acid is slowly poured into the tank until a solution that is about 25 per cent acid is obtained. As the acid combines with the water, a considerable amount of heat is generated which causes the acid to act more rapidly. Files having fine teeth may be sharpened in from three to five minutes, while files with coarse teeth generally require from five to twenty minutes. A second batch of files can be treated in the same solution by adding a little sulphuric acid. After two or three batches of files have been treated, however, it is usually necessary either to heat the solution or make a new one.

Nitric and Hydrochloric Acids: Another process consists of immersing the files in a warm aqueous solution of nitric acid and hydrochloric acid, consisting preferably of about equal parts of the acids and of water. This solution should be kept at a constant temperature. After the files have been treated with the acid

solution, they should be washed in lime water or some other alkaline solution, and then wiped with oil.

Adding Acid to Water: Caution must be exercised in mixing sulphuric acid and water. Always pour the acid into the water slowly; never pour water on the acid, as an explosion may result, the same as when babbitt is poured into a wet box or mold. In both cases the explosion is caused by the sudden generation of steam. Commercial hydrochloric acid diluted with about 10 per cent water and heated to near the boiling point can be used instead of sulphuric-acid solution. The diluted hydrochloric acid has the advantage of being safer to handle.

As soon as the files are removed from the acid solution, they are washed in running water and dried rapidly by heating. After drying, they may be dipped in gasoline containing about 5 per cent paraffin or engine oil. The gasoline evaporates, leaving a thin coat of oil on the files.

File Terms. The *length* of a file means the distance from the point to the heel and does not include the tang. The *heel* is that end of the file body adjacent to the handle. A *blunt file* is one having the same sectional shape from the point to the tang. The coarse grades of single-cut files are sometimes called *floats*. *Safe-edge* means that the edge or side is smooth and without teeth, and may be presented to a surface that does not require filing. *Over-cut* is a term used to describe the first series of teeth on a double-cut file. *Up-cut* means the series of teeth superimposed on the over-cut series of a double-cut file. *Re-cut* means the working over of old worn-out files by annealing, grinding out the old teeth, re-cutting, hardening, etc. Re-cutting is seldom practiced at the present time. The term *superfine* (or super) cut is used by Lancashire file-makers to designate the grade of cut known in the United States as "dead-smooth." *Taper* is used to distinguish a file having tapering sides from one that is blunt or straight. A file is tapered when it is thinner at the point than at the middle, and is full-tapered when thinner at the point and the heel than at the middle. Custom has also established the use of the term "taper" as a short name for "three-square" or triangular handsaw files.

File Testing. The quality of files can be tested by a special machine which records the endurance and capacity for removing metal, by producing a curve or diagram on sectioned paper wound about a cylindrical drum connected with the file reciprocating mechanism, so as to make one revolution to 120,000 strokes of the file. On these diagrams, the horizontal distances represent the number of strokes made by the file being tested and the vertical distances, the number of cubic inches of metal removed. Tests

show a remarkable difference in the quality of files, some being worn out after removing less than one cubic inch of iron, and cutting at the rate of only one cubic inch per 10,000 strokes; whereas, files of good quality remove 12½ cubic inches and cut at the rate of 5 cubic inches per 10,000 strokes.

It has been estimated that the useful life of a file is, on an average, 25,000 strokes, which is equivalent to two full working days of ten hours each.

Filing Machines. Filing may be done mechanically especially for such work as filing the openings in blanking dies or whenever a power-driven mechanically-guided file is desirable. One type of filing machine is of the reciprocating type. Another filing machine adapted to die and similar work is of the continuous filing type. This machine is designed along the general lines of a band saw and the files, which are attached to a band or chain, provide a continuous filing or cutting action. As the filing movement is always in the working or cutting direction, there being no reversal, the life of the files is greatly increased. This machine may be equipped with files of whatever cross-sectional shape conforms closest to the outline of the die. The file-holding band may be uncoupled at one point for inserting or removing a die. One advantage of a die-filing machine, as compared with hand filing, is that straight or flat surfaces can be filed without difficulty because the file is mechanically guided and moves in a straight line, whereas, when filing by hand, it is difficult to do the work accurately.

Fillets. Fillets are concave moldings used in patternmaking to fill in the sharp corners formed by surfaces lying in planes at an angle to each other. They are very important in making machinery castings as the strength of the cast piece is greatly increased by their use, and its liability to fracture is greatly lessened. Fillets are either "stuck" or "planted." A stuck fillet is one that is worked from the solid, and a planted fillet is one made separately and applied. Planted fillets, which are the ones commonly used, are made of wood, leather, beeswax, putty, and other plastic materials. Metal fillets have also been used to some extent, but are not very popular, as they are hard to fasten and soon work loose.

Wood fillets are made by the patternmaker with a round sole plane and are used where corner radii of 1 inch and over are required. *Leather fillets* are in general use for filleting of 1-inch radius or less, and may be worked into any corner whether the angle be acute or obtuse. They are usually worked in place with a spherical-ended tool. Owing to their pliability, leather fillets

can be used either on straight work or regular and irregular curves. *Beeswax* and other plastic materials are quite commonly used for fillets of small radii.

Filters for Air. The air cleaner most widely used for the extraction of dangerous dusts of small dimensions is the cloth filter, either of the bag or screen type. When well engineered and maintained, filters are capable of collecting 99% or more of dusts as small as 0.5 microns. The optimum velocity through the filter medium depends upon the dust loading of the entering air, the plugging characteristics of the dust, the maximum allowable pressure drop, the frequency of cleaning and other factors. The air volume per square foot of cloth varies from ½ to 6 c.f.m. in commercial filters. A filtration rate of 4 f.p.m. is usually satisfactory for the recovery of precious metal polishing dusts, foundry dusts and pulverized mineral dusts such as cement, feldspar, limestone and similar materials. The filter is inherently a high-resistance cleaner. Its filtration efficiency depends to a considerable extent on the accumulation of deposited dust. The formation of the dust mat, on the other hand, increases the resistance substantially. The pressure drop is greatest just before the filter is shaken and is lowest immediately after cleaning.

Filters for Removing Fine Particles from Coolants and Lubricants. Filters are used for re-conditioning the cutting oils or coolants on certain types of machine tools and they may also be applied to lubricating oil systems. The value of some sort of filtration of grinding coolant to remove particles of wheel grit and metal chips has been recognized in connection with certain grinding operations for many years. The need for grit-free coolant is most apparent when fine-grit wheels are used to produce a high finish on work such as hardened steel rolls for cold-rolling metal. The reason is that fine-grit wheels are dense and particles of abrasive carried in the coolant between the wheel and the work cannot embed themselves in the pores of the wheel face; consequently, they are likely to scratch the work.

Mechanical Filters: Mechanical filters have been developed which can be installed in the coolant supply line of most cylindrical grinders. Their use is frequently recommended by grinding machine manufacturers, and, in many cases, machines are sold equipped with filters. Their application seems to be principally for the improvement of finish, although other advantages have been proved that should make their use much more general. Not only are scratches reduced or prevented and a better finish obtained, but the grinding wheel faces are kept clean, so that they cut better and require less dressing. This results in a reduction of abrasive costs through longer wheel life and higher production,

because of the better wheel action and less time lost in wheel dressing.

Magnetic Filter: One type of filter for removing iron and steel particles from coolants or lubricating oils, operates magnetically. It is claimed that the Frantz "FerroFilter" will remove particles as fine as 1/25,000 inch from suspension in liquids. It is applicable to machine tool cutting oil systems and to the lubricating systems of Diesel engines, aircraft engine test and run-in stands, reduction gears, etc. The liquid material to be cleaned is passed through a stack of magnetized screens. These screens are enclosed in a cylindrical casing. The screens, although offering comparatively little resistance to the flow of the liquid, present up to 8000 feet of strongly magnetized edges which catch and hold the particles or iron until the machine is shut down. The filter is then demagnetized and flushed. The filter may be operated by direct current at 110 to 120 volts, but portable tube-type rectifiers are available which will supply the required current from a sixty-cycle, alternating-current lamp socket.

Finished Surface Inspection. Very slight cracks and other surface irregularities that cannot be seen with the naked eye are detected by magnetic particle or fluorescent penetrant inspection. In the former, magnetic particles (spread over the surface of the workpiece, which has also been magnetized) form a readily discernible pattern over the surface discontinuity. In the latter, a fluorescent penetrant (passed over the surface of the workpiece) seeps into the cracks, etc. which is later easily seen by an inspection under near ultra-violet light.

Finishing Steels. Tool steels of this class are especially adapted to finishing cuts as in turning long shafts. Finishing steels are very similar to carbon steels in that they have a very high cold hardness. In addition, they contain enough alloying elements to enable them to retain their hardness somewhat better at the higher speeds than is possible with the straight carbon steels.

Low-Cobalt Finishing Tools: As a general rule, finishing tools should be tough and hard. Low-cobalt high-speed steel answers this requirement very satisfactorily. The advantages of this steel over the high-tungsten high-speed steel are due to the high temperature it can stand and to its ability to maintain a good cutting edge under long finishing cuts. This material has been found better adapted for screw machine work than the high-tungsten or even the high-cobalt high-speed steel.

Finishing Steels for Drills: Drill steels generally known as "finishing steels" are a low-tungsten type of tool steel. This is an intermediate type of steel sold as either carbon, super-carbon, or alloy tool steel. The carbon content usually ranges from about

1 to 1.25; the tungsten, from 0.2 to 2.7; and chromium, from 0.5 to 1.2. Some of these steels also have 0.2 or 0.3 per cent of vanadium. Drills made from these finishing steels are used to advantage in place of plain carbon steel tools when increased cutting speed and longer life are required. They cannot, however, be compared with high-speed steel drills.

Finish Marks or Symbols. The finish marks used on drawings may show merely what surfaces are to be finished or they may also indicate with varying degrees of exactness, the quality of the finish. The letter *f* has been used extensively to show that some kind of finish is required. It is common practice to so place this letter that its cross-line intersects the line on the drawing representing the surface to be finished. The practice of some concerns is to use the capital letter *F* with the foot of the letter resting on the line indicating the surface to be finished. The quality of a finished surface may be indicated definitely and precisely by a number representing a micro-inch reading and also by a graphic record on a chart. See Finish or Surface Quality.

American Standard Finish Marks: A surface to be machined or "finished" from unfinished material such as a casting or a forging should be marked with a 60-degree "V," the bottom of the "V" touching the line representing the surface to be machined or finished. A code figure or letter should then be placed in the opening of the "V" to indicate the quality of the finish desired. The meaning of these code figures or letters should then be indicated by notes at the bottom or side of the drawings.

Fin of Drop-Forging. On a drop-forging the fin is the excess metal that is forced out of the die impression into the space between the upper and lower die sections.

Fire and Explosion Hazards. Conditions which may cause fire or explosion present hazards which must be considered when installing machinery and equipment, particularly of an electrical nature. The kinds of hazards involved have been grouped into four classes by the National Board of Fire Underwriters, according to the degree of danger involved. Many types of electrical equipment, such as motors and controls, are designed to meet the safety requirements called for by one or more classes of hazard.

Class I locations are those in which inflammable volatile liquids, highly inflammable gases, mixtures, or other highly inflammable substances are manufactured, used, handled, or stored in other than their original containers. There are four groups in this class:

Group A: Atmospheres containing acetylene.

Group B: Atmospheres containing hydrogen or gases or vapors of equivalent hazard, such as manufactured gas.

Group C: Atmospheres containing ethyl ether vapor.

Group D: Atmospheres containing gasoline, petroleum, naphtha, alcohols, acetone, lacquer solvent vapors, and natural gas.

Groups *A* and *B* present the most severe hazards and there has been considerable difficulty in attempting to standardize electrical equipment to meet them. Group *C* hazards are less severe, and there is a wide range of motors and controls constructed to withstand an internal explosion of the gases or vapors covered by Group *D* without causing such harm as would interfere with their successful operation.

Class II locations are those in which combustible dust is, or may be, held in suspension in the air in sufficient quantities to produce explosive mixtures or in locations where it is impracticable to prevent such combustible dust from collecting on motors, lamps, or other electrical devices that are liable to be overheated because normal radiation is prevented. There are three groups in this class:

Group E: Atmospheres containing metal dust.

Group F: Atmospheres containing carbon black, coal, or coke dust.

Group G: Atmospheres containing grain dust.

Protection against these hazards is afforded by the use of dust-tight enclosures which have accurately machined joints.

Class III locations are those in which easily ignitable fibers of materials producing combustibles are handled, manufactured, or used.

Class IV locations are those in which materials covered in Class III are stored. Protection against these hazards is afforded by the use of enclosing cases which will not allow the escape of any sparking and which will not become overheated when in use.

Firebrick Properties. Brick intended for use in furnaces, flues, and cupolas, where the brickwork is subjected to very high temperatures, is generally known as "firebrick." There are several classes of firebrick, such as fireclay brick, silica brick, bauxite brick, chrome brick, and magnesia brick. Ordinary firebricks are made from fireclay; that is, clays which will stand a high temperature without fusion, excessive shrinkage, or warping. There is no fixed standard of refractoriness for fireclay, but, as a general rule, no clay is classed as a fireclay that fuses below 2900 degrees F. Fireclays vary in composition, but they all contain high percentages of alumina and silica, and only small percentages of such constituents as oxide of iron, magnesia, lime, soda, and potash. A great number of different kinds of firebrick are manufactured to meet the various conditions to which firebricks are subjected. Different classes of bricks are required to withstand different temperatures, as well as the corrosive action of gases,

the chemical action of furnace charges, etc. The most common firebrick will melt at a temperature ranging from 2830 to 3140 degrees F.; bauxite brick, from 2950 to 3245 degrees F.; silica brick, from 3090 to 3100 degrees F.; chromite brick, at 3720 degrees F.; and magnesia brick, at 4950 degrees F.

Fire Cracks. In brass and other alloys, so-called fire cracks are defects due to molecular changes produced by mechanical deformation, which appear during the annealing process. German silver is particularly liable to this defect.

Firecrete, Light-Weight. A light-weight material from which any refractory shape can be obtained quickly by simply mixing it with water and casting it in a form. After being in the form twenty-four hours, the shape is ready to be placed in service. Sixty-five pounds of material are required for each cubic foot of finished construction. Suitable where difficult brick construction is encountered, for lining furnace doors, and for making small monolithic linings. Can be subjected to working temperatures up to 2200 degrees F. Especially advantageous in the case of intermittently operated furnaces, because of its exceptionally low heat storage capacity.

Fire Hose Couplings. See Hose Couplings.

Fire Point of Oil. The fire point or fire test of an oil is the temperature at which the oil will catch fire and continue to burn. The fire point and the flash point are two important properties in oil, particularly when the oil is used under conditions where it may be exposed to high degrees of temperature, as, for example, in hardening rooms or electric transformers. To make a flash point of fire test, proceed as follows: Place a quantity of oil in an open vessel. Heat it slowly and uniformly and note the temperature by a thermometer immersed in the oil. From time to time, let a small flame impinge upon the surface of the oil; the lowest temperature at which a slight explosion or flash takes place is the *flash point.* Continue this test until the oil will be set afire by the explosion or flash. The temperature when the oil will ignite and burn continuously should be noted on the thermometer. This temperature is the fire point. See Flash Point of Oil.

Fits. The American Standard for Preferred Limits and Fits for Cylindrical Parts, ASA B4.1, gives the following definitions:

Fit. Fit is the general term used to signify the range of tightness which may result from the application of a specific combination of allowances and tolerances in the design of mating parts.

Actual Fit. The actual fit between two mating parts is the

relation existing between them with respect to the amount of clearance or interference which is present when they are assembled. (Fits are of three general types: clearance, transition, and interference.)

Clearance Fit. A clearance fit is one having limits of size so prescribed that a clearance always results when mating parts are assembled.

Interference Fit. An interference fit is one having limits of size so prescribed that an interference always results when mating parts are assembled.

Transition Fit. A transition fit is one having limits of size so prescribed that either a clearance or an interference may result when mating parts are assembled.

Basic Hole System. A basic hole system is a system of fits in which the design size of the hole is the basic size and the allowance is applied to the shaft.

Basic Shaft System. A basic shaft system is a system of fits in which the design size of the shaft is the basic size and the allowance is applied to the hole.

Fits, Machine. See Driving Fits; Forced Fits; Shrinkage Fits, and Expansion Fits.

Fittings. The term "fittings" as applied to pipe work, includes the various parts used in pipe lines for connecting different pipes, viz., ells or elbows, tees, and crosses, as well as pipe flanges. They are made from cast iron, wrought iron, malleable iron, or composition metal. See Pipe Fittings.

Fixtures. Fixtures may be defined as special devices, used in the manufacture of duplicate parts of machines, or manufactured devices in general, intended to make possible interchangeable work at a reduced cost, as compared with the cost of producing each part individually. The piece of work to be machined is held and properly located in the fixture, the fixture, in turn, being held on the table of the machine on which the operation is to be performed. The terms "jig" and "fixture" are frequently used interchangeably, but, as a general rule, a jig is a tool which, while it holds the work, at the same time also contains guides for the respective tools to be used (for example, a *drill jig*), while a fixture only holds the work while the cutting tools are performing the operation upon the piece, without containing any special arrangements for guiding the tools. The fixture, therefore, must itself be securely held or fixed to the machine on which the operation is performed; hence, the name. Fixtures are mainly used on milling machines, planers, boring mills, and lathes.

Fixture Thread. See Electric Fixture Thread.

Flame Cutting. See Oxy-acetylene Method of Cutting Steel and Iron.

Flame-Descaling. This is a process for removing scale from blooms, billets, slabs, forgings and steel castings by means of specially designed oxy-acetylene heating heads. The process is based on the principle that when high-temperature heating is applied to the scale or oxide skin on a piece of cold metal, the scale expands and breaks away from the base metal, due to the different rates of expansion of the scale and the steel.

Flame-Hardening. Wherever there is the problem of excessive wear due to scraping or cutting action, seizing, or galling, the application either of flame-hardening or hard-surfacing methods may offer an effective solution. In flame-hardening, the oxy-acetylene flame serves only as a heating medium, no change taking place in the chemical composition of the material being hardened. The process differs fundamentally in this respect from casehardening or nitriding. The steel is simply heated with the oxy-acetylene flame to a temperature at which subsequent quenching, usually with water or air, will increase the surface hardness.

Advantages of Flame-Hardening: Flame-hardening advantages include: (1) No change of chemical composition in the hardened surface. (2) Easy application to limited areas. (3) Possibility of increased hardness, due to the rapid quenching action possible because of the large volume of cold metal beneath the heated surface. (4) Low stresses between the hard surface and the relatively ductile core; this prevents spalling or "shelling out." (5) Feasibility of application to sections as thin as ¼ inch or even thinner, with proper technique. (6) Scale-free surfaces, due to rapidity of treatment.

Heating Methods: The heating operations of flame-hardening may be classified as stationary, progressive, and spinning. In the stationary procedure, sometimes called "spot-hardening," both torch and work are motionless during the operation. With the progressive method, the flame and work are moved relative to each other, and the metal is quenched immediately after it is brought up to temperature. Thus, in flame-hardening a plane surface, the lighted oxy-acetylene torch is directed along the surface at the maximum speed that will permit heating the surface zone above the critical point of the steel, while immediately behind the flame is a stream or spray of water which progressively quenches the heated surface. The speed is determined by operating variables, such as flame intensity, type of steel under treatment, and temperature desired. The usual speeds are from 6 to 8 inches per minute, although the range may extend from 4 to 10 inches per minute.

In the spinning method, principally applied to round parts, the torch is stationary and the work is rotated before the flame. When the entire area has reached the hardening temperature, the quench is applied, with the work still rotating. The time for hardening by this method varies from a few seconds to two or three minutes.

Quenching: For quenching, many devices can be used, ranging from a small stream of water from a round nozzle to a carefully designed spray nozzle. Spinning operations are better controlled by quenching with a large volume of water under low head, which simulates total immersion. Certain steels, too sensitive to be quenched with water, may be treated with a soap-water solution or a soluble cutting oil in water.

As a rule, flame-hardening operations should be followed immediately by a low-temperature draw to relieve quenching stresses; this can be conveniently done in an oil bath or oven. Although generally recommended, the drawing operation is not always necessary, since by carefully controlling the quantity and application of the quenching medium or by delaying its application, the operation becomes "self-drawing."

Applications: Owing to the fact that the flame-hardening is adaptable to complicated parts with less danger of distortion or other faults than other heat-treating methods, it finds important use in the treatment of the teeth of large gears, rail ends, pump liners, crane wheels, tractor shoes, sheave wheels, machine ways, valves, crankshafts and camshafts, and many other parts.

Steels Suitable for Flame-Hardening: In selecting a suitable steel for flame-hardening, it may be said that plain carbon steels can be hardened satisfactorily by this process, provided the carbon content is more than 0.40 per cent. The upper limit of carbon is dependent upon the method of hardening used, but steels having a carbon content up to 0.70 per cent or even higher, depending upon the sections, can be successfully flame-hardened. Alloy steels of a wide range of compositions can be satisfactorily treated by this process, but in general, because of economic factors, its application is restricted to the low or medium alloy types, that is, those in which the percentage of the principal added elements is small.

Steel Forgings for Gears: While many types of steel forgings can be successfully flame-hardened, S A E 4640 and S A E 6145 are recommended. These steels are usually readily obtainable, comparatively inexpensive, and give uniformly dependable results. A lower-priced steel, S A E X1340, is used especially for some machine tool gears where the tooth loads do not require the maximum possible surface hardness and the sections are light enough to harden and draw to the required core hardness. In

specifying S A E X1340, the usual practice is to require that "a 1-inch round section must harden in oil to a minimum hardness of 42 Rockwell C."

Preliminary Heat-Treatment of Steel Forgings: Since flame-hardening has no effect on the core, it is essential that the core strength be obtained before the blanks are machined. The following preliminary heat-treatment is specified: Normalize, reheat, quench, and draw to the required hardness. The required degree of core hardness will vary from 235 to 302 Brinell, according to the stresses to which the gears are subjected in service. In a few cases, where the tooth loads are extremely high, a core hardness of from 302 to 341 Brinell is specified.

The preferred practice is to purchase the forgings in the untreated state, rough-machine them, rough-cut the teeth, heat-treat them to the desired core condition, and then finish-machine them, finish-cut the teeth, and flame-harden them. The maximum resistance to shock is generally obtained by reheating after quenching to about 1200 degrees F., from which temperature, in the case of carbon steel at least, the metal may be again quenched or slowly cooled. This treatment results in a very fine grain.

Preliminary Heat-Treatment of Steel Castings: For flame-hardened gears, steel castings containing from 1.00 to 1.50 per cent manganese and 0.35 per cent carbon are recommended. It is well to include in the specification the statement: "Analysis should be suitable for flame-hardening." The exact analysis may then be left to the steel foundry. The castings must be given a preliminary heat-treatment, preferably by the foundry, in order to obtain the required core structure.

Flame-Hardening Machines: Special machines have been developed for flame-hardening the teeth of gears. While flame-hardening of gear teeth has been done by hand, this method is dependent upon human judgment, and there is danger of overheating, cracking, and non-uniform hardness. Gas-cutting equipment of the standardized types has a limited application in gear hardening, but special machines are preferable. A modern type heats and quenches both sides of a gear tooth simultaneously. Previously only one side of a tooth was hardened at one time. This caused unequal stresses in the tooth, resulting in distortion. Furthermore, the temper on the first side was often slightly drawn when the second side was heated for hardening. These difficulties are eliminated when both sides of the teeth are hardened at once.

Flame, Neutral. See Neutral Flame.

Flamenol. Synthetic insulating compound similar to rubber in its characteristics, but does not contain rubber and is not com-

bustible; can be compounded, filled, calendered, and extruded in much the same manner as rubber. Used as an insulation on cable because of being highly resistant to moisture, acids, alkalies, and oils; is available in a variety of colors.

Flame-Softening. Most steels can be flame-cut without detrimental effect, but there are some harder grades of steel, particularly the low-alloy high-strength types, which tend to harden along the cut edge as a result of the cutting operation. A process, known as flame-softening, provides a simple and economical means for restoring the steel to its soft condition. Multi-flame heating heads, which usually operate simultaneously with the cutting, heat the body of the metal after cutting, so that the cut edge is annealed or tempered.

There are three methods of applying flame-softening. The first is applicable to plate thicknesses up to and including 1½ inches, in which case a single multi-flame heating head, either directly before or after the cutting tip, is directed toward the top of the cut edge. The second treatment is applicable to thicknesses from 1½ to 4 inches, and is similar to the first one, with the exception that an additional multi-flame head is directed at the bottom of the cut edge. The third method is applicable to thicknesses above 4 inches, the multi-flame head being directed against the face of the cut edge following the cutting operation, but before the steel is cooled to room temperature.

The flame-softening process has been successfully applied to cut edges of gusset plates and web plates for buildings and bridges, to structural plates, railroad cars, the cutting of high-strength steel products in steel warehouses, and the finish-treating of carbon steels of 0.40 per cent or more in steel mills.

Flange Steel. So-called "flange steel," which is generally used for the heads of steam boilers, is an especially tough and ductile quality of open-hearth steel. The A. S. M. E. boiler code specifications for flange steel are as follows: Manganese, 0.30 to 0.60 per cent; phosphorus, acid, not over 0.05 per cent; phosphorus, basic, not over 0.04 per cent; sulphur, not over 0.05 per cent. An analysis is to be made by the manufacturer from a test ingot taken during the pouring of each melt, and a copy given to the purchaser or his representative.

Flash-Ex. A metal coating eliminating the necessity of grinding or chipping weld spatter from the metal surrounding a weld. The white and pigmented coating prevents the adhesion of spatter to the welded parts, dies, or welding-holder jaws. After the welding operation, any spatter is merely brushed off. This metal coating is used in resistance welding to prevent the dies and welding-holder jaws from becoming jammed due to spatter.

Flash Point of Oil. In specifying oil for various purposes, a flash point and a fire point are often specified. If oil is heated slowly, it will vaporize, forming an inflammable and explosive mixture with the air over the surface of the oil, and at a certain temperature it will be found that this vapor will flash up, if ignited, but the main body of the oil will not ignite. On further heating, a temperature is reached when the production of vapor is rapid enough to maintain a continuous flame, and then the body of the oil catches fire and burns. The *flash point* is the lowest temperature at which the vapor will flash up without setting the oil on fire; the *fire point* is the lowest temperature at which the oil will burn. In some oils these points come so near together that it is impossible to distinguish between them, while in other oils they may be 20 degrees or more apart. The flash point is not an indication of the value of an oil for any particular purpose. It is simply an indication of the temperature at which the oil gives off vapors in such proportion that they form an inflammable mixture with the air. The flash points of mineral lubricating oils vary, with few exceptions, from 300 to 600 degrees F. The flash point can be considerably exceeded if the oil is protected by steam.

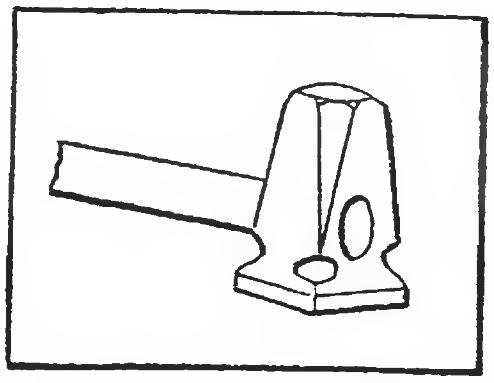
Flasks for Molding. Flasks or molding boxes confine the sand used in making all molds that are not formed in the floor. They may be of wood or iron and in shapes or sizes to suit the work. The iron flasks are superior, as there is less likelihood of straining the mold in handling it, and the smaller sizes are made interchangeable, the pins and holes of a given size flask being the same. *Snap flasks* are hinged at one corner or side and are held together with a snap fastened at the opposite corner. This type of flask confines the sand while the mold is being made, but may be removed as soon as the mold is finished, so that it can be used again before the mold is poured. Snap flasks are used for light work and are usually square, rectangular, or round.

Flat File. A flat file is parallel in both longitudinal sections, from the heel to the middle, and tapered in both sections from the middle to the point, the thickness of the point being about two-thirds and the width about one-half that of the stock from which the file is made. The flat file is one of the most common files in use and is not confined to any specific class of work, but is employed for a great variety of purposes. Ordinarily, the teeth are double-cut, and either bastard, second-cut, or smooth. A single-cut flat file is preferred for some classes of work.

Flat Key. A flat key differs from a saddle key in that it bears against a flat surface on the shaft. The key is not sunk into the shaft but it gives it a fairly good grip. This type is not adapted

to heavy work, however, owing to the excessive strains to which the hub is subjected, as the shaft tends to turn.

Flattening Test. This term as applied to tubing refers to a method of testing a section of tubing by flattening it until the inside walls are parallel and separated by a given distance—usually equal to three times the wall thickness for seamless tubes and five times the wall thickness for lap-welded tubes. Boiler tubes subjected to this test should show no cracks or flaws. The flattening test applied to *rivets*, consists in flattening a rivet head while hot to a diameter equal to 2½ times the diameter of the shank or body of the rivet. Good rivet steel must not crack at the edges of the flattened head.



Blacksmith's Flatter

Flatters. The tools used by blacksmiths for finishing the flat surfaces of forgings are called *flatters* and *sets*. Flatters are generally made from 2¼ to 2¾ inches square on the face, which should be slightly crowning in the center and the edges well rounded off to prevent their leaving sharp marks upon the work. Sets are of various shapes and sizes, but all are modeled more or less on the same principle as flatters and are used for similar work. It is of advantage to use a flatter with its edges well rounded for fillets, and one with sharp square edges to finish corners which must be sharp.

Flat Tongs. This is a type of tongs used by blacksmiths. These tongs usually have a small longitudinal V-shaped depression the full length of the flat jaws, so that they can be used to hold round stock or square stock cornerwise.

Flat Turret Lathe. The flat turret lathe is so named because the turret is a flat circular plate mounted on a low carriage to secure direct and rigid support for the tools, from the lathe bed. The tools, instead of being held by shanks inserted in holes in the turret, are clamped firmly onto the low circular turret plate so that they do not overhang, but have an unyielding support directly below the cutting tools. This type of turret lathe was introduced in 1891, and was designed by James Hartness. Lathes of the flat-turret class are sometimes referred to as *turntable lathes*.

Flemish Finish on Brass. The so-called Flemish finish can be given to brass with a solution composed of ¼ ounce of sulphuret of potassium; from 1 to 2 ounces of white arsenic; 1 quart of muriatic acid; and 10 gallons of water. The arsenic should be dissolved in a part of the acid by heating, and then mixed with the balance of the acid and water. Two ounces of

sulphuret of potassium in a gallon of water may also be used if it is heated to 160 degrees F. One ounce of sulphuric or muriatic acid in a gallon of water darkens the color produced by this last mixture.

Flexible Couplings. Flexible couplings are the most common mechanical means of compensating for unavoidable errors in alignment of shafts and shafting. When correctly applied, they are highly efficient. For joining lengths of shafting without causing loss of power from bearing friction due to misalignment, and for use in direct motor drives for all kinds of machinery, the value of the flexible coupling is now generally recognized. The fact that limeshafting will sag if of considerable length, makes the use of a flexible connection essential. Flexible couplings are not intended to be used for connecting a driven shaft and a driving shaft that are purposely placed in different planes or at an angle (joints for such service are usually called universal joints) but are intended simply to overcome slight unavoidable errors in alignment that develop in service. There is a wide variety of flexible coupling designs; most of them consist essentially of two flanged members or hubs, fastened to the shafts and connected by some yielding arrangement. The question of balance is an important matter in coupling selection or design, as an increasing number of couplings are used in connection with steam turbines, high-speed motors, and many other classes of machinery. It is not sufficient that the coupling be perfectly balanced when installed, but it must remain in balance after wear has taken place.

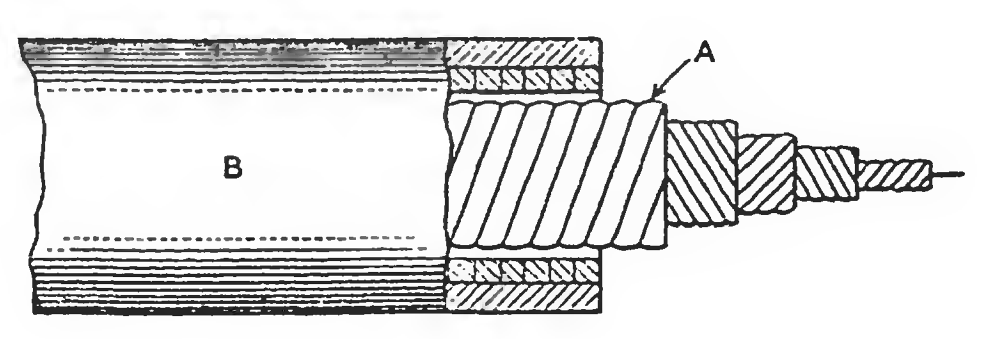
For small drives operating at moderate speeds where low first cost is the only consideration, there are several types of flexible couplings using leather, rubber, or fabric as the flexible element. Special types of couplings have been developed for continuous process work, as on steel rolling mills, where the capacity of the coupling for misalignment is really important. In designing couplings for such service, it is usual to sacrifice a considerable amount of over-all length in order to use what really amounts to two flexible couplings connected by an intermediate shaft, which may vary in length according to the probable maximum amount of off-center misalignment. An all-metal type of flexible coupling is adapted for heavy-duty work, because of the smaller size involved, longer life, and less cost—first and last.

Many drives are started suddenly, and one machine may impose a fluctuating or vibratory load on the other. For such drives it is often desirable to have a cushioning effect between the machines, which is supplied by coil springs or by laminated bundles of springs in the all-metal types. Flexible fabric couplings are noiseless in operation and yield sufficiently to cushion the shock

when the clutch is engaged for starting. For this reason, the parts of the transmission are not subjected to such severe stresses as would otherwise be the case. These couplings are said to be durable and strong, but their use is restricted to "straight line" drives or cases where the driving shaft is inclined at an angle of only a few degrees.

Flexible Shafting. Flexible shafting is used for transmitting motion from a source of power usually to some kind of tool or abrasive wheel, and it is so constructed that the driven tool or other device can be moved in any direction, owing to the flexibility of the shaft. Flexible shafting is sometimes used for driving a mechanically-guided tool, such as an auxiliary grinding wheel, which is held in the tool-post of a lathe or planer, but, in most applications of flexible shafting for the transmission of power, the object is to secure a free or universal movement of the driven member. For instance, a common type of portable grinding outfit consists of a motor which is mounted on a truck and drives a grinding wheel by means of a flexible shaft; as the wheel is held and guided by hand, it can be presented to any surface very readily. These flexible-shaft grinders are used for grinding castings or for cleaning castings by replacing the grinding wheel with a wire scratch brush. Flexible shafting is also extensively used for such work as the grinding of dies, driving small polishing wheels, driving drills of the portable type, rotating dental tools, and certain classes of surgical instruments, and for a great variety of other purposes, requiring a flexible transmission of power.

Flexible shafting consists of an inner core and an outer casing or covering. The core revolves within the casing and transmits motion from the source of power to the driven member. One type of core is composed of several layers of steel wire which are coiled or wound closely upon each other. (See Illustration.) Every alternate layer from the small one in the center to the outer layer is wound in an opposite direction. The cores of some flexible shafts are composed of links which are so formed and



Sectional View of Wire-wound Flexible Shaft

joined together that the required amount of flexibility is obtained.

Floating Core. A core in a mold for making a casting is termed a floating core when it is not firmly supported and is lifted from its position by the molten metal as it flows into the mold. Floating cores are often the cause of unsound castings. The buoyant effect of the molten iron on a core is equal to about three times the weight of the core, if the core is solid, and very much more than that if it is hollow.

Floating Foundations. See under Foundations for Machinery.

Floating Levers. See Differential or Floating Levers.

Floating Tool-Holders. A tool is said to "float" when it is not held rigidly but is free to move within certain limits. The floating or free movement may be in one direction only or in any direction. Many reamer-die- and tap-holders are of the floating type as they allow the die or tap to move in the direction of its axis, so that it is free to follow its own lead in case the forward movement is retarded by the backward pull or drag of the turret or tool-slide to which it may be attached. When a tool-holder is arranged to allow a die, tap, reamer, or other tool to move laterally or possibly in any direction, this is to permit the tool to align itself in case a hole is slightly off center. When the work to be operated upon is placed in a chuck either by hand or automatically from a magazine, a lateral or universal floating movement for the tools is especially desirable because of the difficulty of chucking parts in perfect alignment. Some tool-holders which are supposed to have a free floating movement to compensate for errors of alignment do not have this free movement when the tool is at work, because then there is considerable frictional resistance between the driving lugs or surfaces of the tool-holder.

Flooded Lubrication. See under Lubricating Systems.

Flow Meter. The electrically operated flow meter provides means for accurately measuring the total flow of steam, water, air, gas, oil, etc., through pipes. Due to the electrical principle of operation, the indicating, curve-drawing and integrating instruments can be located any distance away from the pipe where the flow is being metered.

Fluid-Compressed Steel. Steel which has been subjected to compression before the ingots were entirely solidified, in order to secure a perfectly solid and homogeneous mass, is known as fluid-compressed.

Fluid Couplings. See Couplings of Fluid Type.

Fluid Power Transmission. The term "fluid power" has been applied to various forms of fluid or hydraulic transmissions on

machines requiring either a straight-line or a rotary drive. In general, the transmission system includes some form of pump to force oil into a cylinder for straight-line movements or into a fluid power motor for rotary motion, and, in addition, suitable controls as for varying the speed or to meet other operating requirements. This general type of transmission has flexibility of control and compactness of design. Since transmissions of the fluid or hydraulic type are applied to many different kinds of machines and other forms of mechanical apparatus, both the pumps and fluid motors are made in different types and in a wide range of sizes. See Hydraulic Transmissions.

Fluorine. Fluorine is a pale greenish-yellow gas with a sharp odor. Its specific gravity is 1.265. The gas becomes liquid at a temperature of —187 degrees C. (—305 degrees F.), and the liquid becomes solid at a temperature of — 223 degrees C. (— 369 degrees F.). The most important compound of fluorine is that with hydrogen, with which it forms hydrofluoric acid (HF). Hydrofluoric acid is important because it dissolves glass, and can, therefore, be used for etching on glass. It is also used as an etching acid on metals.

Flutes. The grooves which are cut in such tools as taps, reamers, drills, milling cutters, etc., in order to form cutting edges on the tools, and at the same time provide room for the chips produced by the cutting tools when in operation, are known as *flutes.* It is important that the flutes in the various types of machinists' tools be properly shaped, and special forms of milling cutters are generally used for producing the flutes. The cross-sectional shape of the flute varies according to the type of tool. See Taps; also Hob Flutes.

Fluxes. When metals are welded or soldered together, some substance which is known as a *flux* is used to prevent oxidation and to clean the surfaces to be joined, so that a solid homogeneous joint will be obtained. Fluxes are also used in connection with the smelting of metals, to promote fluidity, prevent oxidation, and remove objectionable impurities in the form of a slag.

In ordinary steel welding, fluxes are used to protect the heated surfaces from oxidation and to dissolve any oxide that may have formed. See Soldering Fluxes; Welding Fluxes; Aluminum Welding Fluxes.

Fly-Cutter. The fly-cutter is a simple type of formed milling cutter that is often used for operations that will not warrant the expense of a regular formed cutter. The milling is done by a single tool or cutting edge which has the required outline. This tool is held in an arbor having a taper shank the same as an end-

mill. The advantage of the fly cutter is that a single tool can be formed to the desired shape, at a comparatively small expense.

Flywheel. Flywheels are applied to engines and to many classes of machinery to equalize the energy exerted and the work done, and thereby prevent great or sudden changes of velocity. The extent to which velocity changes may take place is the determining factor in all flywheel design. When the energy supplied to the flywheel becomes less than the work done by the machine, the wheel will begin to turn slower and slower, because it gives up its stored-up energy to supply the deficiency. The heavier the rim and the greater its velocity, the greater the energy that may be stored up in the flywheel, and the less will be the change of speed for a given amount of energy stored up. One hundred feet per second may be regarded as a safe rim speed for cast-iron wheels made in one piece, providing the design is such that there are no severe shrinkage strains in the casting. Ordinarily, strains exist, and, therefore, about 85 feet per second is as high a rim speed as should be considered good practice. If the wheel is made in halves or sections, the efficiency of the rim joint must be taken into consideration.

Flywheel Equalizing Sets. See Equalizing Sets.

Follow-Boards. Very light or thin patterns that are difficult to keep in shape during the building process, or are apt to be rammed out of shape in the foundry, are built on wooden forms called *follow-boards.* The follow-board is usually made to conform to the inner or cope side of the pattern and is used to build the pattern on, and also in the foundry to support it in the sand. Many master patterns for stove and furnace work are made in this way.

Follow Dies. Follow dies are used for work which must be cut from the stock to the required shape, and, at the same time, be provided with holes or perforations. The principle of the follow die is that while one part of the die punches the hole in the stock, another part blanks out the work at a place where, at a former stroke, a hole or opening was punched, so that a completed article results from each stroke of the press; in reality, however, two separate operations have been performed, the operation being a progressive one in which the holes are first pierced, after which the stock moves along until the pierced section is in line with the blanking punch. Follow dies are also called "progressive" or "tandem" dies.

Follower. The name "follower" is often applied to the driven member of a gear train or other mechanism having a part that

receives motion from another member and follows it; usually the "follower" in a train of mechanism is the last driven member. The follower of an engine piston of the sectional type is the plate or cover that serves to retain the piston-rings. In cam design, the follower is the part that is reciprocated by the cam surface, or the part to which the cam imparts motion. Usually the follower is provided with a roller at its end in order to reduce the contact friction to a minimum.

Follow-Rest. For turning long slender parts, such as shafts, etc., a follow-rest is often used for supporting the work. A follow-rest differs from a steadyrest in that it is attached to and travels with the lathe carriage. One type has adjustable jaws which are located nearly opposite the turning tool, thus providing support where it is most needed. Other follow-rests have, instead of jaws, a bushing bored to fit the diameter being turned, different bushings being used for different diameters. The bushing forms a bearing for the work and holds it rigidly. Whether a bushing or jaws are used, the turning tool is slightly in advance of the supporting member.

Foot. A foot is a unit of length; 1 foot = 12 inches = 0.3048 meter = 304.8 millimeters.

Foot Candle. The unit of measurement of the intensity of the light received by an object. One foot candle is the amount of light on a surface one foot away from a standard one candlepower light source. See Candlepower.

Foot-Pound. Work is the result of the two elements, force and motion. When no motion results from the action of a force, no work is done. A jack-screw supporting a weight does no work, except when the screw is turned so as to raise the weight.

In order to calculate the work done, the magnitude of the force applied is measured in pounds and the distance moved in feet. The product of these quantities, obtained by multiplying them together, is the work in *foot-pounds*. Or, briefly stated, work = force $\times$ distance.

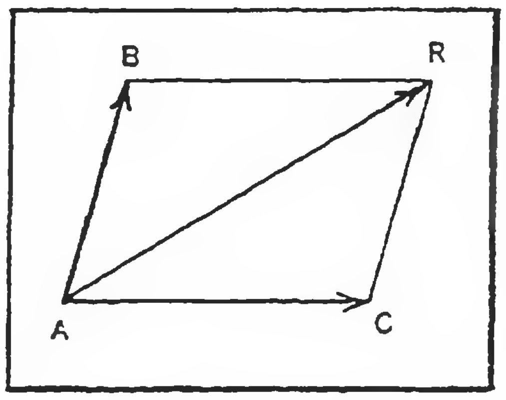
The foot-pound is called the *unit of work*, and may be defined as the work done by a force of one pound acting through a distance of one foot. In the estimation of work it is sometimes more convenient to multiply the resistance overcome by the distance, than to multiply the force applied by the distance, in which case work = resistance $\times$ distance.

Foot-Pounds per British Thermal Unit. See Heat Equivalent of Work.

Foot-Valve. A "foot-valve" is sometimes placed at the lower end of the suction pipe of a pump to prevent the suction pipe from

emptying while the pump is at rest; consequently, when the pump is first started, it does not have to exhaust the air from the suction pipe, and prompt starting of the pump is secured, assuming that the foot-valve is tight enough to retain the water in the suction pipe. This valve is of especial value when the suction lift or vertical height of the pipe is considerable. When the pump is exposed to low temperatures during cold weather, it is advisable to have a drain fitted to the lower end of the suction pipe in order to empty the latter, in case the pump is to remain idle for some time and there is danger of freezing.

Force. A force, in mechanics, is defined as any cause tending to produce or modify motion. The units in which a force is usually measured are pounds or tons. A force has three characteristics which, when known, determine it. They are direction, place of application, and magnitude. The *direction* of a force is the direction in which it tends to move the body upon which it acts. The *place of application* is generally assumed to be a point, as the center of gravity. The *magnitude* is measured in pounds, as already stated. The single force which produces the same effect upon a body as two or more forces acting together, is called their *resultant*. The separate forces which can be so combined are called the *components*. The finding of the resultant of two forces is called the *composition* of forces, and the finding of two or more components of a given force, the *resolution* of forces. If two forces applied at a point are represented in magnitude and direction by the adjacent sides of a parallelogram (*AB* and *AC* in the accompanying illustration), their resultant will be represented in magnitude and direction by the diagonal *AR* drawn from the intersection of the two component forces.



Force Diagram

Forced Draft. The forced draft method consists in forcing air under pressure into the ash-pit of a furnace, or into the retort of an underfeed stoker, and thus causing it to pass upward through the bed of fuel. It has the advantage of low first cost, and is also easily applied to old furnaces where it is desired to increase the power of the plant without installing additional boilers. One of the disadvantages of this system is that the pressure maintained in the ash-pit and furnace is liable to blow ashes and smoke into the fire-room if forced too hard. With moderate pressures, this may be avoided if care is taken to shut off the blast-pipe before opening either ash-pit or furnace doors. In admitting air to the ash-pit for forced draft, the ducts should be arranged

to spread it as much as possible, and on this account it is usually introduced either through openings in the bridge wall or in the bottom of the ash-pit just inside the doors. Steel plate blowers of the centrifugal type are commonly used for forced draft. These may be of the regular form used for ventilating purposes, or of the multivane type, which is a common form of centrifugal fan having a large number of shallow vanes or blades.

Forced Draft Pressures. The pressure required for mechanical or forced draft depends upon the rate of combustion, thickness of the fuel bed, and character of the fuel used. Average conditions will usually be covered between the extremes of from 0.75 to 2 inches of water column, corresponding to 0.44 and 1.16 ounce per square inch, respectively. The volume of air or gas to be handled by the blower will depend upon whether the forced or the induced system is used. For forced draft, about 18 pounds of air is required per pound of coal, which is approximately 230 cubic feet at 60 degrees F. The higher temperature of the gases passing through the blower when induced draft is employed makes it necessary to increase this volume of air about 30 per cent, to care for the expansion.

Forced-Feed Lubrication. See under Lubricating Systems.

Forced Fits. "Forced" or "pressed fit" is the term used when a pin, shaft, or other cylindrical part is forced into a hole of slightly smaller diameter, ordinarily by the use of a hydraulic press or some other type of press capable of exerting considerable pressure. A forced fit has a larger allowance than a driving fit, and therefore requires greater pressure for assembling. The proper allowance for a forced fit depends upon the mass of metal surrounding the hole, the size of the work, the kind and quality of the material of which the parts are composed and the smoothness and accuracy of the pin and bore. Crankpins, car-wheel axles, and similar parts which must be held very securely, are given forced or pressed fits rather than driving fits. The allowance per inch of diameter usually ranges from 0.001 to 0.0025 inch, 0.0015 inch being a fair average. Ordinarily, the allowance per inch decreases as the diameter increases; thus the total allowance for a diameter of 2 inches might be 0.004 inch, whereas, for a diameter of 8 inches, the total allowance might not be over 0.009 or 0.010 inch. In some shops, the allowance is made practically the same for all diameters, the increased surface area of the larger sizes giving sufficient increase in pressure. See Shrinkage Fits.

Force of a Blow. A body that weighs W pounds and falls S feet from an initial position of rest is capable of doing WS foot

pounds of work. The work performed during its fall may be, for example, that necessary to drive a pile a distance d into the ground. Neglecting losses in the form of dissipated heat and strain energy, the work done in driving the pile is equal to the product of the impact force acting on the pile and the distance d which the pile is driven. Since the impact force is not accurately known, an average value, called the "average force of the blow," may be assumed. Equating the work done on the pile and the work done by the falling body, which in this case is a pile driver and then transposing:

$$\text{Average force of blow} = \frac{WS}{d}$$

Force or Forcer. A "force" or "forcer" is a block of metal which forces sheet stock into every crevice in the impression of an embossing die. The term "force" is also used in connection with die-sinking, where it is often confused with the word "hub"; a *hub*, however, is a hardened steel punch used to form an impression in a die, and to use the word "force" in this connection is incorrect. A force is not employed in the making of the die, but a part of the tools for producing a finished product in an embossing die. Forces are made from different materials, depending upon the character of the work, the design of the die, and the thickness of the metal being stamped.

Forces, Couples. See Couples of Forces.

Forge Air Pressure. The air pressure for a forge commonly varies from 2 to 4 ounces per square inch, with an average of about 3 ounces. A pressure of 4 ounces at the blower has been recommended when the average number of fires does not exceed ten, and a pressure of 5 ounces when the number is more than twelve. Small forges with the blower close to them are adequately supplied with 1½ ounces pressure. If the blower is some distance away and a long discharge pipe with many bends leads to the forge, even though the latter be small, it may be necessary to carry 3 ounces pressure or more, to overcome the friction in the air ducts. The volume of free air required by the average forge fire is about 140 cubic feet per minute. The exhaust fan for a blacksmith shop should have a capacity approximately four times that of the forge blower, and should operate under a pressure of about ¾ ounce.

"Forge Welding." A heavy-duty electric resistance welding process known as "forge-welding" makes it possible to spot-weld heavy steel and iron sections heretofore considered impossible to weld with conventional equipment. With this process, such work can be spot-welded almost as easily and rapidly as sheet metal.

The method consists in first applying pressure to the work and then interrupted current, after which a hammering action is superimposed on the electrode. Under high pressure and with sufficient heat, the surfaces of the work are brought into such intimate contact that when additional impact pressure and intermittent heat are applied, a "forged" weld of superior quality is obtained. To secure the forging effect and still hold the work under pressure, a compound-action "Hydro-Booster" is used. With it, a rapid succession of blows can be superimposed upon the initial constant pressure under which the work is being held.

Portable spot-welding guns can also be used for resistance "forge-welding." With such equipment, the process differs in that pressure is applied in two stages—first, a welding or contact pressure, and then a heavy "squeeze" or forging pressure.

Forging Brass. See Brass Forging.

Forging by Coining Process. This method of finishing small forgings which are required in large quantities, is by squeezing in a powerful press equipped with suitable dies, those parts of the forgings which must be finished accurately to a given form and size. This method represents the application of the coining-press principle to the finishing of various forged parts, such as different kinds of levers, spring shackles, axle spindles, head lamp brackets, steering and fan support arms, pedals, and connecting-rods. The parts of the forging which require coining or squeezing have a small allowance to provide metal for filling the die impression, and the squeezed parts are finished to size in one stroke of the press with the same degree of accuracy as is obtained by the removal of surplus stock through cutting or machining operations. The coining type of press is used, although the term "squeezing press" has been applied to it on account of the variety of work which now comes within its range. See Cold Forging; also Cold-pressed Forgings.

Forging Hammers. See Hammers, Forging.

Forging Machines. Forging machines are made in a variety of designs, some being intended especially for bolt and rivet heading, and others for more general work. The form or shape into which a part is forged is governed by dies of the required shape and also by a heading tool or plunger which bends or upsets the heated bar of metal and forces it into the die impression. The die may have a single impression, or two or three impressions may be required in order to forge the part by successive operations. The reciprocating motion for the heading tool is obtained from a crankshaft which connects with the plunger slide by a pitman or connecting-rod.

On one type of forging machine, the crankshaft is driven through a clutch mechanism, so that the operator can control the number of revolutions the crankshaft makes before stopping, the arrangement being similar in principle to that of an ordinary punch-press. The clutch is tripped by means of a foot-treadle and the crankshaft is driven from a flywheel or gear wheel which revolves continuously. If but a single blow is required, the operator removes his foot from the treadle immediately after tripping the clutch, so that the machine stops automatically at the end of the backward stroke and after making one revolution. In case two or more continuous revolutions are required, the foot-treadle is held down until the required number of blows have been struck.

With another type of machine, what is known as a *lock* or *stop motion* device is used instead of a clutch. This mechanism is also controlled by a foot-treadle, and the device is so designed that the die mechanism is started from rest as the crankshaft, which rotates continuously, reaches the extreme end of the backward stroke. Upon releasing the foot-treadle, the movements of the forging mechanism stop automatically. Forging machines are equipped with some form of relief mechanism, so that, in case a piece of stock should be accidentally caught between the dies, no serious damage would be done.

Forging Presses. Hydraulically-operated presses or the steam-hydraulic type are commonly used for forging large ingots, and are considered preferable to the steam hammer because they exert a steady pressure upon the forgings instead of a sharp blow, with the result that the forging action extends throughout the entire ingot, whereas the steam hammer tends to spread the surface metal without acting upon the center of the ingot to the required degree. An hydraulic press exerts a continuous pressure which forces the semi-fluid material of a forging to flow under compression, which process tends to increase the density of the material. It is thus evident that, from the standpoint of improving the quality of the material in forgings, the press is superior to the hammer. Another advantage of the forging press over the steam hammer is that, for machines of equal capacity, the press, being entirely self-contained, requires a much lighter foundation, while the hammer must have a very massive foundation under the anvil block. The first cost of the forging press is higher than that of a steam hammer, but the difference in the cost of foundation alone tends to equalize the original investment.

Forging Presses of Crank Type. Forging presses of the double-crank type are used for the manufacture of hammers, axes, pickaxes, adzes, mattocks, hoes, etc. A series of dies is arranged

side by side and the part is forged in one or several heats by passing it from die to die. The slide is usually adjustable vertically, although these presses are sometimes furnished without slide adjustment and also without a clutch, for work requiring a continuous operation of the press, and where the design of the dies is such that no adjustment is needed.

Formed Cutters. When pieces having an irregular outline are to be milled, it is necessary to use a cutter having edges which conform to the profile of the work. This is called *form milling*, and the cutter a *form* or *formed* cutter. There is a distinction between a *form* cutter and a *formed* cutter, which, according to the common use of these terms, is as follows: A formed cutter has teeth which are so relieved or "backed off" that they can be sharpened by grinding, without changing the tooth outline, whereas the term "form cutter" may be applied to any cutter for form milling, regardless of the manner in which the teeth are relieved. As indicated by this distinction between "formed" and "form" cutters, these cutters are provided either with regular milling cutter teeth or with eccentrically-relieved teeth. They are generally provided with the latter form, because in that case they can be ground on their faces without changing the form of the cutter. Form cutters are used for milling parts of special shapes to the required form. The small parts of sewing machines, guns, typewriters, and other pieces having an irregular and intricate shape are milled with formed cutters. The simplest types of form cutters are concave and convex cutters, the outline of which is a half-circle. These are used for milling half-circles, cutting half-round grooves, and forming half-round edges. Formed cutters are made in a large variety of shapes and are used for many different purposes.

Formed Cutters for Spur Gears. The invention of a milling cutter for forming gear teeth dates back prior to 1782. This cutter (now in the possession of the Brown & Sharpe Mfg. Co.) was made by Jacques de Vaucanson, a French mechanic. Evidently, the teeth were cut with chisels as they are very fine and rather crudely formed. Comparatively little is known about the types of early milling cutters used for gearing, etc., but the invention of the formed milling cutter in 1864 by J. R. Brown marked a great step in advance, as the contour of the cutting edge was not affected by successive sharpenings. This type of cutter is widely used for cutting gear teeth by the formed cutter method. See Gear-cutters.

Formex. Magnet wire insulated with a synthetic resin which is tougher and more flexible than ordinary enamel coatings and which takes up much less space. The electrical properties are as

good as those of ordinary enameled wires, with higher resistance to abrasion. When severely twisted and then subjected to a temperature of 260 degrees F. for one hour, ordinary enameled wire cracks, while Formex wire is not affected. This new type of insulation has been found to have improved qualities in the actual manufacture of many electrical products. It gives the designer an opportunity to reduce the size of many products of which this wire is an integral part.

Form Grinding. The grinding of machine parts by using a broad wheel which is shaped to conform to the shape required, and without traversing either wheel or work laterally, is known as *form grinding*. The wheel is wide enough to cover the surface to be ground, and, for round work, is fed straight in, thus grinding the entire surface at the same time, without a traversing movement such as is common to ordinary cylindrical grinding. For ordinary shapes, truing of the wheel is done without difficulty, and simply requires a special truing fixture which serves to guide the truing diamond mechanically. The term "form grinding," as applied to the manufacture of machine and automobile parts, is generally used to refer to the production of both straight and irregular-shaped surfaces. For round work, the term is used to indicate that the wheel is fed straight in without any traverse of the wheel or work. In order to differentiate between form grinding of straight and irregular surfaces, other names for the grinding of plain surfaces have been suggested, such as straight-in grinding, and wide-wheel grinding.

Formica. Formica is a non-metallic material made from sheets of cotton duck, the sheets being thoroughly impregnated with redmanol resin and made infusible and insoluble by the application of heat and pressure. An important application of formica is in making noiseless gears and pinions. Such gears are used for timing and ignition drives and on a miscellaneous variety of other machinery.

The tensile strength of formica in the direction of the laminations is 10,000 to 12,000 pounds per square inch, and the compressive strength, 24,500 pounds per square inch. The compressive strength perpendicular to the laminations is 47,000 pounds per square inch. The Brinell hardness is 34.4 and the hardness by scleroscope test, 65. The specific gravity is 1.38. The moisture and oil absorption is practically nil. The coefficient of linear expansion is about 0.00002 per degree Fahrenheit up to 150 degrees.

Formica Machining. Blanks can be cut from sheets of "Formica" either by a band saw or by trepanning tools in a boring mill or a drill press. To saw blanks, first describe a circle as

a guide line, then use a 21-gage 3½-point saw running at a speed of 5000 feet per minute. The saw should be sharp, with a 1/64-inch set on both sides.

In drilling, use an ordinary high-speed drill whose point is ground to an included angle of 55 to 60 degrees. Another method is to grind the drill point slightly off center. The feed must be rapid and caution used to prevent the drill from lagging in its work, and the speed must be 1200 revolutions per minute.

For all machine operations on "Formica" gear material, provision must be made in grinding for the tools to clear themselves. For reaming, the entry of the reamer and the reaming process must be rapid. There must be no lag between the end of the reaming operation and the withdrawal of the reamer.

In turning the outside diameter and sides of blanks, the tools must be sharp and have 3 to 5 degrees more rake than is common practice for metal. A cutting speed of 750 feet per minute, which is equal to 720 revolutions per minute on a 4-inch diameter blank, is recommended. The depth of the cut can be 1/16 to ⅛ inch, but the feed should be 0.010 inch, regardless of the depth of the cut.

Teeth may be cut on a hobbing machine, shaper, or milling machine. The speed of the cutter should be 150 feet per minute, and the feed from 0.023 to 0.040 inch per revolution. It is advisable to back up the blank to prevent fraying or breaking out of the material as the cutter comes through. The backing plates can be economically made from hard wood.

Forming Dies. Forming dies are a type of dies in which a blank is formed into a hollow shape by simply being pushed into a cavity of the required shape in the die, or a previously drawn cup is given a different shape by compressing it between a punch and die which conform to the shape desired. Drawing dies are also used for the formation of cup-shaped articles, but the drawing process differs from forming in that the stock is usually confined between two surfaces so that, when drawn radially inward from between them, no wrinkles can form. To define the difference between the two types in another way, forming dies shape the metal by compressing and bending it, whereas drawing dies so act upon a flat blank, or a previously drawn cup, that the shape is changed by drawing the metal as the punch moves relative to the die or vice versa.

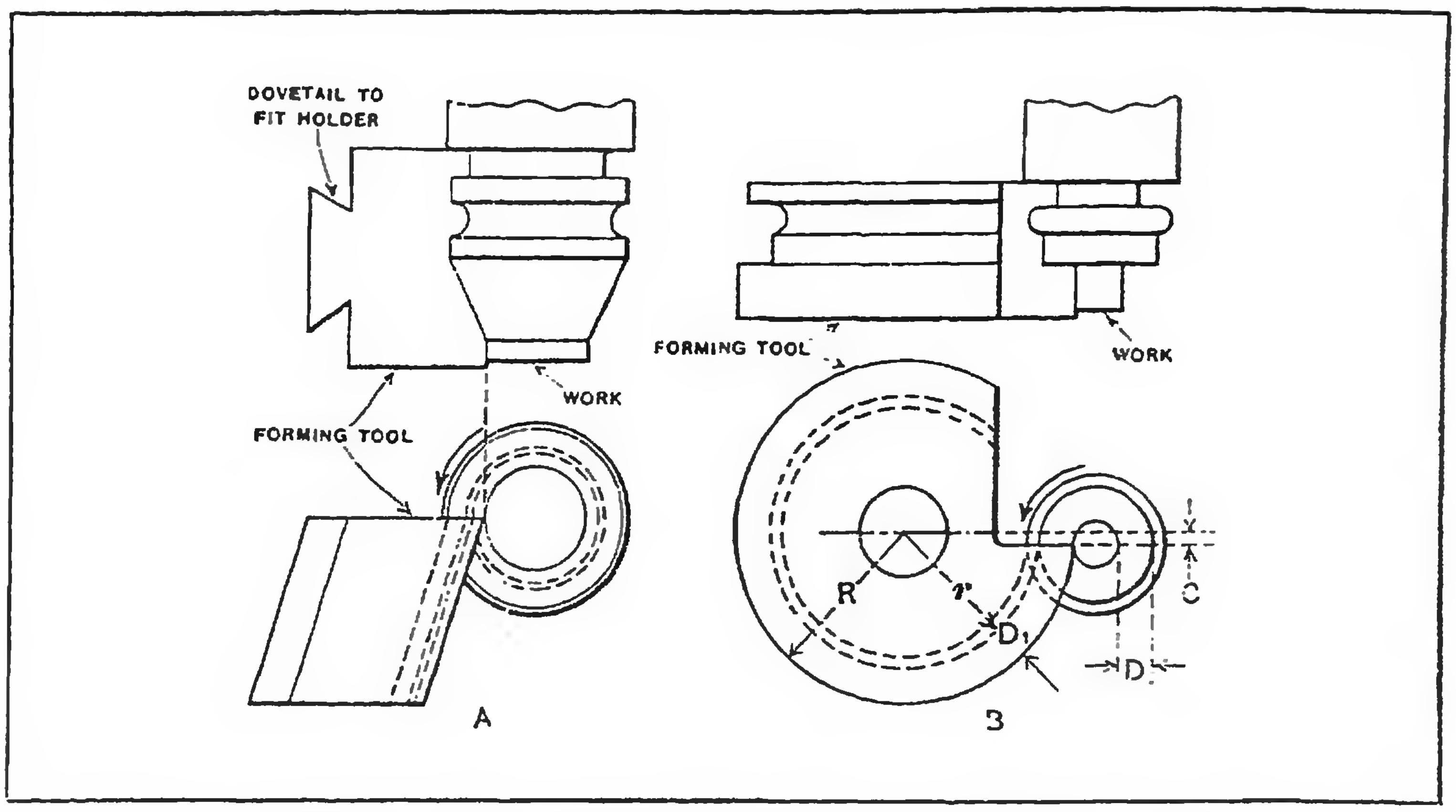
Forming Lathe. What is known as a *forming lathe*, or a *forming turret lathe*, is similar to an ordinary design of turret lathe but usually has a carriage between the turret and the headstock that is arranged for carrying wide-forming tools; in some cases, there is a vertical slide at the rear, so that the forming tool may

be fed in a vertical plane. Some forming and chucking lathes have a cross-slide for the turret and the latter carries the forming tools.

Forming Tools. Forming tools are made in either straight or circular shapes. Forming tools for the lathe or planer are ordinarily made flat or straight. In some cases, a flat formed blade is bolted to a holder, but tools that are to be used very little are often made solid, the formed cutting edge being machined and filed on the flat forged end of the tool. When a number of different tools are needed, it is more economical to make one shank or holder and attach separate cutters or blades of the required form. Diagram *A*, shows a *straight forming tool* of the vertical or straight-faced type. This style of tool is used on automatic turning machines, etc., especially for large work. The *circular forming tool, B,* is used in preference to the flat or straight type for many classes of work, especially in connection with automatic screw machine practice, because it is more easily duplicated after a master tool for turning it is made. The circular tool can be ground repeatedly without changing its shape. The straight form of tool may also be ground repeatedly without affecting the shape, when it is made with a formed surface which is of uniform cross-section. Forming tools are also made which operate tangentially instead of radially; that is, the cutting edge, instead of moving in toward the center of the work, moves along a line tangent to the outside surface being formed.

Formulas. A formula may be defined as a mathematical rule expressed by signs and symbols instead of in actual words. In formulas, letters are used to represent numbers or *quantities*, the term "quantity" being used to designate any number involved in a mathematical process. The use of letters in formulas, in place of the actual numbers, simplifies the solution of problems and makes it possible to condense into small space the information that otherwise would be imparted by long and cumbersome rules. The figures or values for a given problem are inserted in the formula according to the requirements in each specific case. When the values are thus inserted, in place of the letters, the result or answer is obtained by ordinary arithmetical methods. There are two reasons why a formula is preferable to a rule expressed in words. 1. The formula is more concise, it occupies less space, and it is possible to see at a glance, the whole meaning of the rule laid down. 2. It is easier to remember a brief formula than a long rule, and it is, therefore, of greater value and convenience.

In chemistry, a formula is an abbreviation used to designate a chemical compound. It shows how many atoms of different chemical elements are contained in one molecule of the compound. For example, the chemical formula of ferric oxide is Fe_2O_3, which



(A) Straight Forming Tool of Vertical Type
(B) Circular Forming Tool

shows that one molecule of ferric oxide contains two atoms of iron, the symbol of which is Fe, and three atoms of oxygen, the symbol of which is O.

Formula Transposition. A formula can be changed or "transposed" to determine the values represented by different letters of the formula. To illustrate by a simple example, the formula for determining the speed (s) of a driven pulley when its diameter (d), and the diameter (D) and speed (S) of the driving pulley are known, is as follows: $s = \frac{S \times D}{d}$. If the speed of the driven pulley is known and the problem is to find its diameter or the value of d instead of s, this formula can be transposed or changed. Thus: $d = \frac{S \times D}{s}$.

Changing a formula in this way is known as "transposition" and the changes are governed by four general rules.

Rule 1: An independent term preceded by a plus sign (+) may be transposed to the other side of the equals sign (=) if the plus sign is changed to a minus sign (—).

Rule 2: An independent term preceded by a minus sign may be transposed to the other side of the equals sign if the minus sign is changed to a plus sign.

As an illustration of these rules, if $A = B - C$, then $C = B - A$, and if $A = C + D - B$, then $B = C + D - A$. That the foregoing is correct may be proved by substituting numerical values for the different letters and then transposing them as shown.

Rule 3: A term which multiplies all the other terms on one side of the equals sign may be transposed to the other side, if it is made to divide all the terms on that side.

As an illustration of this rule, if $A = BCD$, then $\frac{A}{BC} = D$. Suppose, in the preceding formula, that $B = 10$, $C = 5$, and $D = 3$; then $A = 10 \times 5 \times 3 = 150$, and $\frac{150}{10 \times 5} = 3$.

Rule 4: A term which divides all the other terms on one side of the equals sign may be transposed to the other side, if it is made to multiply all the terms on that side.

To illustrat if $s = \frac{SD}{d}$, then $sd = SD$, and, according to Rule 3, $d = \frac{SD}{s}$. This formula may also be transposed for determining the values of S and D; thus $\frac{ds}{D} = S$, and $\frac{ds}{S} = D$.

If, in the transposition of formulas, minus signs precede quantities, the signs may be changed to obtain positive rather than minus quantities. All the signs on both sides of the equals sign or on both sides of the equation may be changed. For example, if $-2A = -B + C$, then $2A = B - C$. The same result would be obtained by placing all the terms on the opposite side of the equals sign which involves changing signs. For instance, if $-2A = -B + C$, then $B - C = 2A$.

Formula Containing Power of a Number: The power of a quantity or number may be given in a formula, and it may be desirable to transpose the formula so that the number itself may be determined. The formula $V = 0.5236d^3$ is for finding the volume of a spherical body. In this formula, $V =$ the volume in cubic inches and $d =$ the diameter of the sphere. Assume that the formula is to be transposed for determining the value of d. $V = 0.5236d^3$; then $d^3 = \frac{V}{0.5236}$. It follows, then, that the cube root of d equals the cube root of $\frac{V}{0.5236}$, or $\sqrt[3]{d^3} = \sqrt[3]{\frac{V}{0.5236}}$. As $d = \sqrt[3]{d^3}$, then $d = \sqrt[3]{\frac{V}{0.5236}}$. If the volume of the sphere is 4.1888 cubic inches, then $d = \sqrt[3]{\frac{4.1888}{0.5236}} = \sqrt[3]{8} = 2$ inches.

Formula Requiring Extraction of a Root: The following example illustrates how a formula may be transposed to determine the value of a quantity covered by a root sign. If A equals the length of a hypotenuse of a right-angled triangle, B equals the altitude, and C equals the length of the base, then $A =$

$\sqrt{B^2 + C^2}$. If this formula is to be transposed for determining the value of C (lengths A and B being known), the first step is to remove the square-root sign, because C^2 cannot be transposed while it is covered by this sign. If A equals $\sqrt{B^2 + C^2}$, it follows that the square of A equals the square of $\sqrt{B^2 + C^2}$, and the square of $\sqrt{B^2 + C^2}$ is the same as $B^2 + C^2$; that is, the square of the expression is obtained by simply removing the square-root sign. The reason why this is true will, perhaps, be clearer if numerical values are substituted for the letters. Suppose $B = 4$ and $C = 3$, then $\sqrt{4^2 + 3^2} = \sqrt{25} = 5$, and the square of $5 = 25$. The sum of $4^2 + 3^2$ also equals 25.

It is evident, then, that $A^2 = B^2 + C^2$. The expression has now been changed so that it can be transposed, the square-root sign having been removed. Thus, $A^2 - B^2 = C^2$, or, if the formula is written in the usual manner with the letter representing the quantity to be determined placed on the left-hand side of the equals sign, $C^2 = A^2 - B^2$. Now the procedure is the same as for the formula previously referred to for determining the diameter of a spherical body of given volume. Thus, $\sqrt{C^2} = \sqrt{A^2 - B^2}$, and as $C = \sqrt{C^2}$, it follows that $C = \sqrt{A^2 - B^2}$

Foucault Currents. Same as Eddy-currents.

Foundations for Machinery. The materials commonly used are concrete, stone, brick, and wood in conjunction with concrete for machines subjected to considerable vertical shock. The principal characteristics of these materials are briefly as follows: Concrete is an ideal foundation material, as it becomes practically one solid piece and is much cheaper than a masonry foundation. Stone, in addition to being strong and durable, has great vibration-absorbing power, but is quite costly. Brick is not so durable as stone, but is cheaper and available everywhere. In a brick foundation, stones are usually placed under the parts of the machine which rest on the foundation. Good bricks should have plane faces, parallel, sharp edges, and sharp angles; their texture should be compact, and free from holes.

Proper Support for Machine Bed: Machine bases or frames are of two types, namely, those that have inherent rigidity and so have need of support at three points only, and those without inherent rigidity, which must be supported at intervals in order to preserve their form and maintain perfection of alignment. The average machine user attempts to confer rigidity on machines of the latter type by bolting or grouting them firmly to a foundation. Such a procedure is fatal to the satisfactory use of planers, long lathes, and other machines of that type.

The bed of such a machine should be set on a good foundation,

but should never, under any circumstances, be bolted or grouted to that foundation. Instead, it should be supported on suitable wedges or other leveling devices at intervals of from three to five feet. Many shop men assume that a foundation will remain true, and that if a machine bed without inherent rigidity be grouted to the foundation, it will add to the stiffness and strength of the bed and eliminate vibration.

Foundations sometimes settle from ¼ to ½ inch, and planer beds, for example, have been forcibly sprung over ¼ inch by being grouted firmly to a foundation that settled. As a result, the ways were no longer straight, the table vees touched only at the high spots, and the bearing surfaces were soon destroyed. If this machine had been set on leveling blocks, placed at about four-foot intervals, and the leveling blocks had been drawn up as often as necessary to compensate for the settling of the foundation, the planer would have remained accurate.

Types of Machine Foundations: Machine foundations may be divided into rock-supported foundations, pile-supported foundations, and floating foundations. Rock-supported foundations are concrete or masonry structures which rest on rock or hard clay of such bearing power that the foundation does not settle measurably under the load of the machinery. Such a foundation may be in one piece or it may be a series of piers. If a foundation of this kind is obtainable at a reasonable cost, it is the best sort of machine foundation, but even a rock-supported foundation is subject to some seasonal movement, and long beds or frames must not be grouted or bolted to it.

When the foundation, because of the cost or for other reasons, cannot be carried down to the rock, it may be laid upon piles, columns, or beams that are rock-supported. Such a foundation is less subject to seasonal movement, but is more likely to settle at points where it carries concentrated loads.

Floating Foundations: A floating foundation is one laid on an ordinary earth surface which has been properly leveled and compacted. The foundation must be stiff enough so that it transmits the weight equally to all parts of the surface, and large enough so that the distributed load does not exceed the safe bearing strength of the earth. It is usually in the form of a properly designed reinforced concrete slab.

Even a good floating foundation may settle, and provision must be made for keeping the machinery level. If the foundation carries only fixed weights, it can support a number of machines with only slight seasonal changes and very little settling. If, however, the loading varies from time to time, as, for instance, if the slab supports a column supporting a traveling crane, independent slabs should be provided for machines without inherent rigidity, while

a common slab will do for a number of machines whose frames have inherent rigidity.

When a floating foundation is laid near a pile or rock-supported foundation, many masons anchor it to the pile or rock-supported foundation, but the foundation is then not so good as it would be if it were free from such support, for if the earth settles ever so slightly, the foundation will no longer be true, while if the rock foundation be subject to moving loads, the floating slab will continually vary in its level.

Loads on Soils and Rocks: Information about the bearing capacities of soils and rocks is not only useful in structural engineering, but also of value under certain conditions in connection with the installation of very heavy machinery requiring foundations. The ultimate resistance of various soils and rocks will be given in tons per square foot: Natural earth that is solid and dry, 4 to 6 tons; thick beds of absolutely dry clay, 4 tons; thick beds of moderately dry clay, 2 tons; soft clay, 1 ton; gravel that is dry, coarse, and well packed, 6 to 8 tons; soft, friable rock and shales, 5 to 10 tons; sand that is compact, dry, and well cemented, 4 tons; natural sand in a clean dry condition, 2 to 4 tons; compact bed-rock, northern red sandstone, 20 tons; compact bed-rock, northern sound limestone, 25 tons; compact bed-rock granite, 30 tons.

Foundry Coke. See Coke.

Foundry Crane. This is a jib crane frequently used in foundry work. It is generally of heavy construction.

Four-Stroke Cycle. See Cycles of Internal Combustion Engines.

Fractional Horsepower Motor. According to the American standard, a fractional horsepower motor is a motor built in a frame smaller than that having a continuous rating of one horsepower, open type, at 1700 to 1800 revolutions per minute. Such motors are widely used for all types of electrical appliances, refrigerators, oil burners, small tools, etc.

Free Air Capacity of Compressor. See Air Compressor Capacity.

Free-Cutting Stock. The term "free cutting" is applied to stock which may readily be machined and which does not form long, tough chips that tend to clog cutting tools. This free-cutting property is especially important in connection with automatic screw machine and turret lathe practice.

Free-cutting Brass: The standard specification No. 72 of the Society of Automotive Engineers for free-cutting brass rod is as

follows, the composition being in percentages: Copper, 60 to 63; lead, 2.25 to 3.25; iron, maximum, 0.15; other impurities, maximum, 0.50; zinc, remainder.

Free-Cutting Steels: There are several classes of free-cutting steels. S.A.E. composition No. 1112, often called "screw stock," has excellent machining properties. This steel has from 0.08 to 0.13 per cent carbon and from 0.60 to 0.90 per cent manganese. S.A.E. No. X1112 has a similar composition, but with a higher sulphur content which improves the finish and machinability. It is used only when production, speed, and finish are especially important. The open-hearth screw stock (S.A.E. Nos. 1115 and 1120) are somewhat inferior to Nos. 1112 and X1112 in machining properties but possess a much better combination of strength and toughness, and are more dependable for casehardened parts and for such operations as bending, swaging, riveting, and forming.

Freeze-Out. In blast furnace operation, the term "freeze-out" means that the iron and slag in the hearth has set in a solid mass, so that it is impossible to open the tap holes. This trouble is remedied by increasing the heat of the furnace until the metal is again melted.

Freezing Mixtures, Radiator. See Anti-freezing Mixtures.

French Thermal Unit. See Calorie.

French Thread (S.F.) The French thread has the same form and proportions as the American standard (formerly U. S. standard). This French thread is being displaced gradually by the International Metric Thread System.

Frequency. The frequency of an alternating electrical current is the number of cycles or periods per second. The product of 2π times the frequency is called the *angular velocity* of the current. Sixty cycles is the standard lighting frequency in the United States. If a lower frequency is used, fluctuations in the light are likely to occur. At 40 cycles, this flickering is not essentially objectionable, but at 25 cycles, it is quite perceptible, and this frequency is not used for lighting service except in an emergency.

Frequency Changer. Many high-speed motor-driven portable tools and also certain classes of wood-working and metal-working machines are operated by high-frequency current due to the high speed, light weight, and compactness of the motor drive. An essential part of a high-frequency installation is a frequency changer. Frequency changers convert the power of an alternating-current system from one frequency to another, without a

change in the number of phases, or in the voltage. They are either used for obtaining, from a low-frequency system, a frequency high enough for lighting purposes, or as a means of interchanging power between systems operating at different frequencies.

Frequency-changer sets consist either of an induction motor driving a synchronous generator, or a synchronous motor driving a synchronous generator, the latter combination being the most common, especially where two systems are to be tied together and where reversible sets are required.

Another type of frequency changer utilizes a vibrator type of converter. When operated from a 110-volt, 60-cycle power supply, it delivers a 110-volt output at any one of ten different frequencies which can be selected by means of a tapped switch.

Frequency Converter. A frequency converter is a frequency changer in which the windings carrying the currents of different frequency are in the same magnetic field. Thus, a motor-driven induction generator arranged for polyphase excitation of the stator can be so utilized. When the rotor is stationary, it acts as a transformer and delivers an output at the same frequency as the supply; when driven as a generator, it has an output consisting of a voltage and frequency due to transformer action plus a generated voltage and frequency depending upon its speed. Such a converter is usually employed only when the desired output frequency is 25 per cent or more above that of the input.

Friction. Friction is the resistance to motion which takes place when one body is moved upon another and is generally defined as "that force which acts between two bodies at their surface of contact, so as to resist their sliding on each other." The force of friction, F, bears (according to the conditions under which sliding occurs) a certain relation to the pressure between the two bodies; this pressure is called the *normal pressure* N. The relation between force of friction and normal pressure is given by the *coefficient of friction,* generally denoted by the Greek letter μ. Thus:

$$F = \mu \times N, \text{ and } \mu = \frac{F}{N}$$

For well-lubricated surfaces, the *laws of friction* are considerably different from those governing dry or poorly lubricated surfaces.

1. The frictional resistance is almost independent of the pressure per square inch, if the surfaces are flooded with oil.

2. The friction varies directly as the speed, at low pressures; but for high pressures the friction is very great at low velocities, approaching a minimum at about two feet per second linear

velocity, and afterwards increasing approximately as the square root of the speed.

3. For well-lubricated surfaces, the frictional resistance depends, to a very great extent, upon the temperature, partly because of the change in the viscosity of the oil and partly because the diameter of the bearing increases with the rise of temperature more rapidly than the diameter of the shaft, thus relieving the bearing of side pressure.

4. If the bearing surfaces are flooded with oil, the friction is almost independent of the nature of the material of the surfaces in contact. As the lubrication becomes less ample, the coefficient of friction becomes more dependent upon the material of the surfaces.

When a body rolls on a surface, the force resisting the motion is termed *rolling friction*. This has a different value from that of the ordinary, or sliding, friction. Let W = total weight of rolling body or load on wheel, in pounds; r = radius of wheel, in feet; f = coefficient of rolling friction. Then:

$$\text{Resistance to rolling, in pounds} = \frac{W \times f}{r}.$$

The coefficient of rolling friction varies with the conditions. For wood on wood it may be assumed as 0.002; for iron on iron, from 0.002 to 0.005; iron on granite, 0.007; iron on asphalt, 0.012; iron on wood, 0.018.

Friction Clutch. A friction clutch is used for transmitting power from one machine member to another by means of frictional contact between members attached to the driving and driven machine parts. These clutches are made in many different designs, there being, however, four types that predominate; the conical clutch, the radial-expanding friction clutch, the contracting-band clutch, and the friction disk clutch. Friction clutches are used when it is desired to have a smooth and gradual engagement and disengagement of the driving and driven members.

Friction Dial Feeds. See under Power Press Ratchet Dial Feeds.

Friction Gearing. The term "friction gearing" is commonly applied to that type of gearing consisting of a driver made of some substance such as fiber or leather and arranged to operate by rolling in contact with a metallic driven wheel. The driving and driven wheels may be either cylindrical for driving parallel shafts or conical for driving shafts at an angle; when speed variations are required, a small driving disk may be arranged to revolve in contact with the side of a comparatively large driven disk, which also provides for reversing the rotation merely by shifting the driver to the opposite side of its central position on the driven

disk. With the latter arrangement the axes of the driving and driven members are at right angles, and pure rolling contact is not obtained when using a driver of cylindrical form, since it makes contact with the driven disk at various diameters. Friction gearing provides a smooth, uniform drive, but toothed gearing is superior for most purposes because of its positive action and greater power-transmitting capacity. The latter may also be designed to transmit much more power, and at the same time insures maintaining the same relative positions between the driving and driven members, which is important for many classes of mechanism.

"Friction Head" for Lathes. The geared friction head or headstock for turret lathes, etc., has back-gears and friction clutches for engaging either the direct cone-pulley drive or the back-gearing. Many modern designs are equipped with geared headstocks instead of a cone-pulley and either a single driving pulley or a direct-connected motor drive.

Friction Safety Coupling. This is a coupling in which one member is driven by friction, so that in case the power to be transmitted exceeds the normal requirements, the coupling will permit the driven member to slip.

Friction Sawing. In friction sawing the metal piece being cut is in contact with a fast moving saw blade or disk. This contact produces enough friction to heat the material to its softening point. Teeth on the blade or notches on the disk then removes the soft material from the area of contact.

This type of sawing may be done with high-speed band saws, capable of imparting speeds of from 3,000 to 15,000 feet per minute to the friction saw blade, or with electrically driven disk saws, using notched soft steel disks rotating at speeds of 24,000 feet per minute or higher. Investigations have shown that friction sawing with high-speed band saws becomes an economical operation, compared to torch cutting, when the thickness of the material is 9/16 inch or less.

Friction disks are used either on hot or cold material in steel mills or structural shops. The shape of the notch is a definite "V," however, in cases where hot material is to be cut. For cutting cold material, disks made from ordinary boiler plate or a brand of steel known as "soft flange-steel," which contains very little sulphur, are satisfactory.

Friction-Screw-Driven Press. Friction screw or percussion presses are used for forging, hot-pressing, and stamping purposes. The driving mechanism of this type of press has one pulley with

a friction wheel so arranged that either of two friction wheels may be shifted to engage the rim of the heavy central friction- or fly-wheel, attached to a vertical screw. By means of this screw, the ram of the press is raised or lowered. The main feature claimed for this class of press is the cumulative blow delivered, all the energy of the flywheel being utilized as it comes to a dead stop; the operation is essentially that of pressing rather than that of a sharp blow or of hammering. Other advantages claimed for this type of press are that it provides for an "elastic" blow, the drive not being positive, and that, therefore, this design does not require bearings, shafts, etc., of as large dimensions as are required in presses with a positive drive.

Frustum. A frustum is that part of a conical- or pyramid-shaped solid lying between two planes which cut it. These planes are usually parallel but do not necessarily have to be.

Fuel, Calorific Value. See Combustion of Coal; also Calorimeters.

Fuel, Coal Dust. See Coal Dust as Fuel.

Fuel, Colloidal. See Colloidal Fuel.

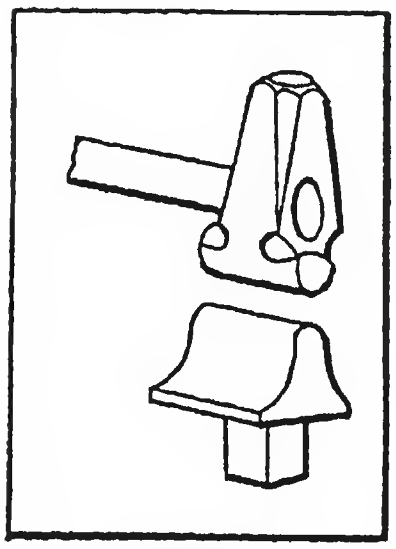
Fuel Oil. Fuel oil has been defined as any liquid or liquefiable petroleum product burned for the generation of heat in a furnace or firebox, or for the generation of power in an engine, exclusive of oils with a flash point below 100° F., Tag closed tester, and oils burned in cotton or woolwick burners. Fuel oils in common use fall into one of four classes: (1) residual fuel oils, which are topped crude petroleums or viscous residuums obtained in refinery operations; (2) distillate fuel oils, which are distillates derived directly or indirectly from crude petroleum; (3) crude petroleums and weathered crude petroleums of relatively low commercial value; (4) blended fuels, which are mixtures of two or more of the three preceding classes.

Fuel Oil, Coal and Gas Equivalents. One gallon of fuel oil equals 13.1 pounds of coal, equals 160 cubic feet of natural gas. One barrel of fuel oil equals 0.278 ton of coal, equals 680.6 cubic feet of natural gas. One pound of fuel oil equals 1.75 pounds of coal, equals 21.3 cubic feet of natural gas. One pound of coal equals 0.763 gallon of oil, equals 12.2 cubic feet of natural gas. One ton of coal equals 3.6 barrels of oil, equals 24,500 cubic feet of natural gas. The heating value of the average mid-continent fuel oil having a Baume gravity of 26.9 is 19,376 British thermal units per pound of oil, and 143,950 British thermal units per gallon of oil.

Fuel Oil Heating Values. In order to determine the calorific values in British thermal units per pound of fuel oils, sixty-four samples of petroleum oils ranging from heavy crude oil to gasoline, representing the products of the principal oil fields in the United States, have been examined for calorific power. It was found that the oils varied in fuel value from about 18,500 to 21,100 B.T.U. per pound. In general, the decrease in calorific power with an increase in specific gravity is regular, so that the relation between the specific gravity and the heat value may be expressed approximately by means of a simple formula, as follows: B.T.U. per pound $= 18{,}650 + 40 \times$ (Number of Degrees Baume — 10).

Fuels, Combustion Elements. See Combustion Elements in Fuels.

Fuller Cell. A Fuller cell is a primary cell or battery in which the zinc anode, which is in the form of a cone, is placed in a porous cup containing a little mercury. This cup is then filled with the electrolyte, which may be either dilute sulphuric acid or a solution of common salt, and is placed in a glass jar which is filled with a depolarizer. The carbon cathode is then put in place. In a standard Fuller cell which has been widely used, the depolarizer is composed of 6 ounces of sodium bichromate, 17 ounces of sulphuric acid, and 56 ounces of water, which ingredients are heated together, forming chromium peroxide. The cell is used for open or closed circuits and has an electromotive force of from 2 to 2.1 volts.



Fullers

Fullers. Fullers are used by blacksmiths for making grooves, breaking-down work, part of which is to be drawn down to smaller dimensions, and for a variety of other purposes. They have a fillet at the point where the light section joins the heavier stock and are made in pairs, top and bottom to match. (See illustration.) Top fullers are fitted to wooden handles and are used in the same manner as sets. Bottom fullers are made with shanks or stems to fit the hardie hole in the anvil.

Function. In mathematics, a function is a quantity or expression which depends for its value upon the value given to other quantities called independent variables or arguments. The circumference of a circle, for example, is a function of its diameter; when the length of the diameter is varied, the circumference varies also. In a table, the values by means of which the table is

entered are known as arguments, while the tabulated values obtained from the table are functions.

Functional Gage. See Gage Classification.

Functions of Angles. In order to introduce the values of the angles in calculations of triangles, use is made of certain expressions called trigonometrical functions or functions of angles. The names of these expressions are: sine, cosine, tangent, cotangent, secant, and cosecant. These expressions are usually abbreviated as follows: sin = sine; cos = cosine; tan = tangent; cot = cotangent; sec = secant; cosec = cosecant.

The *sine* of an angle equals the opposite side divided by the hypotenuse. The *cosine* of an angle equals the adjacent side divided by the hypotenuse. The *tangent* of an angle equals the opposite side divided by the adjacent side. The *cotangent* of an angle equals the adjacent side divided by the opposite side. The *secant* of an angle equals the hypotenuse divided by the adjacent side. The *cosecant* of an angle equals the hypotenuse divided by the opposite side.

It should be noted that the functions of the angles can be found in this manner only when the triangle is right-angled. The secant and cosecant, being merely the values of 1 divided by the cosine and sine, respectively, are not often used in calculations, and are not always included in tables of angular functions. See also Law of Sines and Cosines.

Furlong. A surveyor's length measure; 1 furlong = 10 chains = 220 yards = 660 feet = 201.17 meters.

Furnaces. Furnaces are used in connection with many different operations and processes, such as the hardening of steel, annealing, melting of metals, drying and baking, or for heating parts preparatory to a rolling, forging, or drawing operation. The furnaces used for these different classes of work vary greatly both in regard to size and design. The fuel may be oil, gas, coal, or coke, or electricity may be utilized for producing the necessary heat. The general classification is commonly based upon the position of the firebox or combustion chamber relative to the heating chamber, and these general classes are subdivided into types which are designated, usually, by terms indicating either the method of heating or the kind of work for which the furnace is intended. The name, in some instances, may also indicate some other characteristic constructional feature, as in the case of a *single-end furnace,* which has but one door or opening for the insertion and removal of work, or a *double-end furnace,* which has doors at both ends to provide for a progressive movement of the parts being heated.

Side-fired Furnaces: The side-fired type of furnace is very commonly built with grates for the use of coal. For the use of oil fuel, suitable openings are made in the side walls, and the grates are covered with two or more courses of firebrick. By adjusting the air supply to give a long flame, it is possible to obtain a fairly uniform temperature across a heating chamber from 5 to 7 feet wide. Chambers 8 feet wide have given satisfactory service for some purposes. The conducting of the waste gases under the heating chamber floor will assist in heating the bottom of the work and increase the efficiency of the furnace. This type, with various modifications, has been used extensively for the annealing of brass, copper, and German silver.

End-fired Furnaces: The heat distribution in end-fired furnaces is quite similar to that in the modified form of the side-fired furnace with the two fireboxes at one end. This type is practicable for heating chambers as large as 10 feet square, if the requirements of uniformity are not too strict. Oil fuel is sometimes introduced through the rear wall in the same manner as through the side wall of the side-fired type. This construction was formerly used for annealing brass, but is now more commonly applied to plate heating, etc., where the mass of work is not deep, or, if deep, is relatively short so that the heating chamber can be made short and not require the false arch. Large furnaces for forge work are relatively long, with the stack or a flue at the end opposite the firebox and with doors at the side for the introduction of the work.

Under-fired Furnaces: One of the most common types for small furnaces is the under-fired type. The same principles are sometimes applied to larger furnaces where the firing can be done below the mill floor line, as in a pit or basement. In heat distribution, this is the ideal type of furnace. For high-temperature work, this type has the disadvantage of subjecting the roof of the firebox or combustion chamber to an unusually severe condition, due to the relatively high temperature on top of it as well as underneath. This makes necessary the use of a very refractory material for that portion of the furnace, if the temperature required is high.

Over-fired Type: An over-fired furnace is one in which the combustion chamber is above the heating chamber arch, the combustion gases being carried to the heating chamber through perforations in this arch, and leaving the furnace at the bottom of the hearth. This type of furnace is not commonly used, as the arch construction is expensive and delicate. As heated gas has a tendency to rise, extra draft must be used with an over-fired furnace, to draw the heat down. For extremely high furnaces, this

type can be used in conjunction with the under-fired type. Its construction is also suitable for furnaces requiring removable hearths which are mounted on wheels, where there is no possibility of using the under-fired type.

Internally-fired Type: In some cases the heating chamber and the combustion chamber can be combined. This arrangement is applicable to forge furnaces, rod and rivet heaters, etc., in which an intense heat is required, and the work will not be seriously affected by the direct action of the flame. Melting furnaces of some types are also internally fired. It is but rarely desirable to have the flame proper strike directly against the cold work, as combustion is thereby retarded and soot is often deposited on the work, particularly when oil fuel is used. This type is largely confined to the use of gas and oil fuel.

Hearth-fired Type: In a hearth- or heating-chamber-fired furnace, the initial heat of combustion enters directly into the heating chamber. This type of furnace is usually constructed to allow the gases to come into direct contact with the work, and on account of fuel impurities it is not desirable for the heat-treatment of finished products. In carburizing, however, the work is protected and excellent and economical results can be obtained if there are proper flue outlets. This type of furnace can also be used for annealing if the product later undergoes machining. The removable type of hearth can also be installed in this furnace. See also Electric Furnaces; Oil-burning Furnaces.

Furnaces, Brickwork. There are two prime essentials in furnace brickwork. The first is a quality of brick suited to the required service. The second is the laying of the brick with thin joints. Ordinary practice in laying common brick is utterly unsuitable for firebrick. Standard "9 straight" firebrick, uniform in size and straight within ⅛ inch, should be dipped in a thin mixture of fireclay and water and laid with only what adheres to the bricks, and be rubbed to bed them in the wall, with the bricks in actual contact and the clay mixture merely filling the spaces left by what unevenness there may be on the surfaces. For joints which are necessarily thicker, the clay mixture should be thickened with sea sand, ground firebrick, or carborundum fire-sand which will not shrink as much as the clay. Lime should never be used in the laying of firebrick. Portland cement is used by some masons and is probably desirable as a binder in laying No. 2 quality firebrick where the temperature to which it will be exposed is less than 2500 degrees F. For high temperature duty particularly, the fireclay with which the bricks are laid should be of the same (or better) quality as the bricks, and preferably of the same brand.

Furnace Temperature Control. The temperature of heat-treating furnaces may be controlled in several different ways: First, the furnace operator may take the pyrometer readings and regulate the furnace according to his own judgment; second, the operator may simply adjust the furnace to maintain a given temperature according to signals from a man in charge of the temperature control for all the heat-treating furnaces; third, the signals of the furnace operator may be controlled automatically by a special form of pyrometer which is previously set for whatever maximum and minimum temperatures are desired; and fourth, the control may be entirely automatic. When the control is by some method of signaling, either colored lights or a bell may be used. If lights are employed, there are generally three—a red, white, and green combination being common. These lights are placed near the furnace. The red light may show that the temperature is too high, the white light that it is correct within certain limits (possibly 15 or 20 degrees) and the green light that it is too low. Lights are sometimes used in combination to vary the signals. For instance, when a furnace is loaded with work, the temperature is reduced considerably, the amount depending upon the size of the work and the number of pieces inserted. When the temperature has increased to a certain point, two lights may be switched on to show that it is still considerably below the required temperature, and then one light may be used to show that it is approaching the correct temperature but is still somewhat low. Finally, a different light may indicate that the correct temperature has been reached. See also Pyrometers.

Fuses in Electrical Circuits. An electric fuse is simply a conducting element of such dimensions that it will melt at a predetermined current value, and thus break the circuit and prevent a dangerous temperature increase due to abnormal current conditions. Although arranged in many forms, fuses are simply metal strips or wires that melt, or fuse, when the current reaches the predetermined value. They are divided into two classes: (1) Those designed to protect the circuit and apparatus against both short circuits and definite amounts of overloads. (2) Those designed to protect the system only against short circuits. To the first class belong link and enclosed fuses of the National Electric Code that open on 25 per cent overload. To the second belong the expulsion fuses, which blow at several times the current they are designed to carry continuously. Fuses differ from plain overload circuit-breakers in that they are governed by both the time and quantity of the current, while the overload circuit-breaker is governed solely by the quantity of the current.

Fusible Metals. Fusible metal is the name applied to certain metal alloys generally composed of bismuth, lead, and tin, and sometimes also containing cadmium, which possess the property of melting at comparatively low temperatures. One of the earliest discoveries of a metal alloy which would melt at a low temperature was that of Newton, and the metal known as *Newton's fusible metal* contained 50 parts of bismuth; 31.25 parts of lead; and 18.75 parts of tin. This metal melts at a temperature of 201 degrees F. Another of the early fusible metals was discovered by Darcet. This alloy contained 50 per cent of bismuth; 25 per cent of lead; and 25 per cent of tin; it melts at a temperature of about 200 degrees F. The addition of cadmium produces an alloy which melts at a still lower temperature. An alloy containing 50 parts of bismuth; 25 parts of lead; 12.5 parts of tin; and 12.5 parts of cadmium will melt at a temperature as low as 149 degrees F. By the addition of mercury to the metal discovered by Darcet, the melting point may be reduced to as low as 113 degrees F.

Fusible metals are used for a number of purposes where an alloy that will melt at a low predetermined temperature is required, as in automatic sprinkler heads, in fuses in electric circuits, and for fusible plugs in steam boilers. In automatic fire sprinklers, the rise of temperature resulting from a fire, will melt this metal and the water will be liberated. In steam boilers, fusible plugs are inserted in the furnace crown sheets as a safeguard in case the water level should fall too low. When the fusible plug is no longer in contact with the water, it will be heated to such a temperature that it will melt and allow the steam to escape, thus giving warning of the condition existing in the boiler. See Wood's Metal.

Fusion. The term "fusion" applies to the melting of a solid body, or to the changing of the state of a body from the solid to the liquid condition. It has been established, beyond doubt, that all substances can be transformed into a solid state at some temperature, but, in the case of gases, the temperature must be exceedingly low. It has also been established that all solid substances can be fused or melted and transformed into the liquid state, provided the temperature is high enough. Of the chemical elements, it appears that carbon will stand the highest degree of heat without melting. When changing from the solid to the liquid state, a certain amount of heat is used to accomplish this change. This heat does not raise the temperature of the body and is called the *latent heat of fusion.* This heat is applied to the body at the melting point and is absorbed by the body, although its temperature remains nearly stationary during the whole operation of melting. The latent heat of fusion varies for different substances.

G

Gage. Any tool or instrument used for taking measurements might properly be called a "gage," but this term, as used by machinists and toolmakers, is generally understood to mean those classes of tools which conform to a fixed dimension and are used for testing sizes, but are not provided with graduated adjustable members for measuring various lengths or angles. There are exceptions, however, to this general classification. Gages may be made or set to measure one or more dimensions, and they are used for determining if manufactured parts have been made to agree with prescribed dimensions. If a gage is provided with means for measuring the maximum and the minimum dimensions to which a given piece may be made, it is known as a "limit gage" because it is the means of determining if the part is made within the predetermined limits set for it.

Gages are used in interchangeable manufacture, where a number of similar parts are to be made, all of which may be measured by the same gage and the accuracy of which, within the prescribed limits, may thereby be assured. As the name implies, *working gages* are used by the workmen at the bench or machine in gaging the work as it is being made. *Inspection gages* are used by the inspectors in checking the product to determine if it has been properly made to the required dimensions. *Reference gages* are used for testing or checking the inspection gages from time to time, to make sure that they have not become unsuitable, through wear or otherwise, for the use for which they are intended. These very general classes of gages are made in a large variety of designs and sizes. See Limit Gages; Master Gages; Reference Gages; Temperature Standards for Gages; Air Gages; Optical Comparator Gages.

Gage-Block Adhesion. A remarkable property of precision gage blocks is their adhesiveness to one another. When wrung together they will resist separation in a direction at right angles to the faces in contact, with a force considerably greater than the atmospheric pressure on the area of contact. This phenomenon has caused some to believe that actual molecular adhesion takes place when surfaces that are nearly perfect planes are brought into intimate contact. The error of this theory has been revealed by investigations showing that the adhesion results from the presence of a very thin liquid film. Some blocks of hardened steel were prepared, each weighing 1½ ounces and having surfaces of 0.7 square inch polished flat to within a millionth of an inch of accuracy, and these were used to test the adhesive properties of

many liquids. The contact faces were carefully freed from moisture and grease with alcohol before being coated with a very thin film of the liquid under test. When wrung together while perfectly clean, they fell apart, under their own weight; in order to separate blocks which were held together by films, a force ranging from 17 pounds for Rangoon oil to 22 for lubricating oil, 29 for turpentine, and 35 for condensed water vapor was necessary. After washing the hands with soap, blocks rubbed on them showed adhesion as high as 90 pounds. There was no adhesion from volatile liquids, such as alcohol and benzine; and very little from viscous liquids, such as glycerine and glucose. The microscope showed that the films, drawn out in thin lines, covered only a tenth or less of the metal faces. From varied experiments it appeared that in the case of paraffin film, for instance, the 27 pounds required to part the plates included about one pound due to atmospheric pressure, one to surface tension and 25 pounds to the actual tensile strength of the liquid. The tensile strength of water seemed to be as high as 443 pounds per square inch.

Gage-Blocks. Precision gage-blocks are used in checking or establishing very accurate measurements in machine shops and tool rooms. Gage-blocks are small blocks of steel. Each block in a set has a given thickness or length, and the size of each block is marked on it. The dimension marked on any block represents the distance between two parallel surfaces on opposite sides. If the block, for example, is a 1-inch size, this means precisely 1 inch, within, at most, a few millionths of an inch variation. In other words, precision gage-blocks are practically errorless. Many gage-blocks do not vary from the given size more than two millionths of an inch. The measuring surfaces are not only exact as to the distance between them, but these surfaces must also be flat and parallel with practically no error. Gage-blocks are sold in sets. By combining two or more precision gage-blocks a large range of extremely accurate dimensions can be obtained. The blocks are combined in this way when there is no single block in the set of exactly the size wanted. Gage-blocks or combinations of them are very generally used in machine building plants as ultimate standards of reference for checking inspection or working gages and other precise measuring and gaging equipment.

The total number of gage-blocks in commercial sets vary. One very complete set contains 85 blocks. By placing together different combinations, about 120,000 different gaging lengths are obtainable. Frequently, a given dimension can be obtained by two or more combinations of blocks either for checking one combination against another or for use on different jobs.

Selecting Gage-blocks to Obtain a Given Dimension: Since many dimensions can be obtained by using two or more combina-

tions of blocks, it is preferable, as a general rule, to use the simplest combination or the one requiring the smallest number of blocks. For example, suppose the dimension is 1.9504 inches. Since there is no one block having this dimension, it is necessary to use a combination. Begin by selecting a block for the right-hand figure. Since this is 4, it is necessary to begin by using the 0.1004-inch size. Following the decimal point in the given dimension, we have 0.950; hence, the entire decimal part of the dimension can be obtained by adding the 0.850-inch size (0.1004 + 0.850 = 0.9504). Then, by adding the 1-inch size, the dimension is completed, as shown below at the left. Another method of obtaining this same gaging length is to use a combination of four blocks as shown at the right.

First block	0.1004	First block	0.1001
Second block	0.850	Second block	0.1003
Third block	1.000	Third block	0.950
		Fourth block	0.800
Total dimension	1.9504	Total dimension	1.9504

Gage Classification. The gages used in machine-building plants may be included in one of the following classes, depending upon the use to which the gage is put.

Master Gages: These gages are used only as checks for inspection or working gages. The master for a ring gage is a plug, and the master for a plug gage is usually another plug from which a measurement may be taken for comparison. A basic size gage may also be known as a "master."

Inspection Gages: Gages of this class are used by the inspector to check work coming either from the factory or from outside sources.

Working Gages: Working gages are used in machine-building plants for checking the work, either in a semi-finished or finished state. They are made to a tolerance within the inspection gage tolerance, or larger than the minimum dimension of the work and smaller than the maximum dimension.

Functional Gages: Functional gages are used to test the functional relation of parts, as for example the relation of two such mating parts as a spline shaft and a hole.

Gages for Materials. The thicknesses of sheet metals and the diameters of wires conform to various gaging systems. These gage sizes are indicated by numbers, and in MACHINERY'S Handbook and in other engineering handbooks, will be found tables giving the decimal equivalents of the different gage numbers. Much confusion has resulted from the use of gage numbers, and

in ordering materials it is preferable to give the exact dimensions in decimal fractions of an inch. While the dimensions thus specified should conform to the gage ordinarily used for a given class of material, any error in the specification due, for example, to the use of a table having "rounded off" or approximate equivalents, will be apparent to the manufacturer at the time the order is placed. Furthermore, the decimal method of indicating wire diameters and sheet metal thicknesses has the advantage of being self-explanatory, whereas arbitrary gage numbers are not. The decimal system of indicating gage sizes is now being used quite generally, and gage numbers are gradually being discarded. Unfortunately, there is considerable variation in the use of different gages. For example, a gage ordinarily used for copper, brass and other non-ferrous materials, may at times be used for steel, and vice versa. The gages specified in the following are the ones ordinarily employed for the materials mentioned, but there are in some cases minor exceptions and variations in the different industries.

Gages for Rods. The Brown & Sharpe or American Wire Gage is used for rods of non-ferrous metals, such as brass, copper and aluminum. Stub's Steel Wire Gage is used to some extent for tool steel, drill rod and wire, and the Twist Drill and Steel Wire Gage is used for twist drills and steel drill rods.

Gages for Sheet Metals. The "Manufacturers' Standard Gage" for steel sheets and plates is based upon a weight of 41.82 pounds per square foot per inch thick; hence equivalent thicknesses have been reduced to 40/41.82 of the U. S. Standard Gage established for wrought iron with a basic weight of 40 pounds. The American or Brown & Sharpe Wire Gage is used for sheets of brass, phosphor-bronze, aluminum and German silver. The Birmingham Wire Gage is used for strip steel, steel bands, hoop steel, crucible spring sheet steel, and sheet copper. The Zinc Gage is used for sheet zinc only.

In England the Birmingham Gage legalized in 1914 is used mainly for iron and steel sheets and hoops. This 1914 Birmingham Gage differs from the older Birmingham Wire Gage (see wire gages in MACHINERY'S Handbook). Another older gage known as the Birmingham Metal Gage is used for brass sheets. For aluminum sheets, the Imperial Wire Gage is used in England.

Gages for Tubing. The Birmingham Wire Gage is used for the following classes of tubing: Seamless brass, seamless copper, seamless steel, and aluminum. The Brown & Sharpe Wire Gage is used for brazed brass and brazed copper tubing.

Gages for Wire. The Brown & Sharpe or American Wire Gage is generally used in the United States for all bare wire of

brass, copper (except bare copper telephone wire) phosphor-bronze, German silver, aluminum, and zinc; for resistance wire of German silver and other alloys; for insulated wire of aluminum and copper. The Steel Wire Gage (also known as (1) Washburn & Moen, (2) American Steel & Wire Co., (3) Roebling, and (4) National Wire Gage) is used for bare wire of galvanized and annealed steel and iron (except telephone and telegraph), and also for spring steel wire. The American Steel & Wire Co.'s Music Wire Gage is used for music wire. The Birmingham Wire Gage sizes are very generally used for iron and steel telephone and telegraph wires, but the sizes of bare copper telephone wires, usually conform in the United States, to the Standard Wire Gage used in England. This Standard Wire Gage (also known as the Imperial Wire Gage and as the English Legal Standard) is used in England for all wires. The abbreviation S. W. G. is sometimes used for Standard Wire Gage, also the abbreviation N. B. S. for New British Standard Wire Gage. This gage was legalized in Great Britain in 1883.

Gage Temperature Standards. See Temperature Standards for Gages.

Gage Terms and Definitions. The definitions which follow apply to certain terms used in connection with the American Gage Design Standards.

American Gage Design Standard: The caption "American Gage Design Standard" has been adopted to designate gages made to the design specifications promulgated by the American Gage Design Committee.

Anvil: The gaging member of a snap gage when constructed as a fixed nonadjustable block, or as the integral jaw of the gage.

Adjustable Snap Gage: An external caliper gage employed for the size control of external dimensions, comprising an open frame, in both jaws of which gaging members are so held that one or more pairs can be set and locked to any predetermined size within the range of adjustment.

Solid Snap Gage: An external caliper gage employed for the size control of external dimensions, comprising an open frame and jaws, the latter carrying gaging members in the form of fixed, parallel, nonadjustable anvils.

Taper Lock: Term designating that construction in which the gaging member has a taper shank, which is forced into a taper hole in the handle.

Annular Plug Gage: A shell type plug gage in which the gaging member is in the form of a ring, the external surface of which is the gaging section, the central portion of the web being machined away for the purpose of reducing weight, ball handles being provided for convenience in handling This construction is

employed for plain and thread plug gages in the ranges above 8.010 inches.

Plain Cylindrical Plug Gage: A complete unthreaded internal gage of single- or double-ended type for the size control of holes. It consists of handle and gaging member or members, with suitable locking means.

Progressive Cylindrical Plug Gage: A complete unthreaded internal gage consisting of handle and gaging member in which the "go" and "not go" gaging sections are combined in a single unit secured to one end of the handle.

Reversible Plug Gage: A plug gage in which three wedge-shaped *locking prongs* on the handle are forced into corresponding *locking grooves* in the gaging member by means of a single through screw, thus providing a self-centering support with a positive lock.

Thread Plug Gage: A complete internal thread gage of either single- or double-ended type, comprising handle and threaded gaging member or members, with suitable locking means.

Plain Ring Gage: An unthreaded external gage of circular form employed for the size control of external diameters. In the smaller size it consists of a gage body into which is pressed a *bushing* that is accurately finished to size for gaging purposes.

Thread Ring Gage: An external thread gage employed for the size control of threaded work, means of adjustment being provided integral with the gage body.

Thread Ring Gage Locking Device: Means of expanding and contracting the thread ring gage during the manufacturing or resizing processes. It also provides an effectual lock.

Gage Tolerance. According to the practice of a prominent manufacturer of gages, a tolerance equal to 10 per cent of the tolerance on the work is generally allowed on ordinary working and inspection gages. Thus, if the work tolerance is 0.005 inch, the gage tolerance equals 0.0005 inch for both the working and inspection gages. There is a difference, however, between the maximum and minimum dimensions of the working and inspection gages. The minimum size of the working gage is made 10 per cent of the tolerance *larger* than the minimum size of the inspection gage, and the maximum size of the working gage is made 10 per cent of the tolerance *smaller* than the maximum size of the inspection gage.

Gaggers. In molding, if a body of sand that must be lifted away with the cope extends below the parting, it is strengthened by the use of gaggers. These are usually L-shaped pieces of cast or bar iron. The upper part of the gagger, when reamed tightly between the cope bars, helps to support a hanging body of sand.

Gallon. See Liquid Measure.

Gallotannic Acid. A lustrous, faintly yellowish, amorphous powder. It is soluble in water and alcohol; decomposes at 210 degrees C. It is also known as acid tannic. Its chemical composition is $C_{10}\ H_{14}\ O_9$.

Galvanizing. Galvanizing, in general, is the process of coating one metal with another; the name, however, is more especially applied to the coating of iron or steel products with zinc to prevent corrosion by excluding moisture. Tin and lead are sometimes used as coating materials, but are less effective. Aluminum fulfills all the requirements of a good coating better than any of the commercial metals, but zinc is used because of its lower cost. Iron parts are galvanized by dipping them in molten zinc; this is the process generally known as *galvanizing*. The galvanizing of wire, whether in the form of netting or single wire, is a continuous process, so that the factor of speed is introduced. The amount of zinc deposited can be regulated to a nicety by varying the temperature or speed, or both. The wire passes through a flux and then through the molten metal, and emerges through a part of the bath continually skimmed from oxide. Zinc used for galvanizing should not contain more than 0.5 per cent of iron. It will absorb from 1 to 4 per cent, but each per cent absorbed raises the melting temperature of the bath, so that the zinc becomes thick and pasty; the absorption of iron from the articles being coated and from the sides of the container requires frequent skimming of the bath.

Galvanometer. The galvanometer is an instrument for detecting or measuring electric currents, and is a term generally applied to instruments indicating electric currents on a scale having divisions of arbitrary units, as opposed to the instruments known as "ampere-meters," which give directly the strength of a current in amperes. A great number of different instruments have been devised both for direct and alternating current. The principle on which one of the types of direct-current galvanometer works is based upon the fact that a small magnet, when suspended in the center of a coil of wire through which current is passed, has a tendency to place its magnetic axis in the direction of the magnetic field of the coil at that point. The galvanometer may also be constructed with a suspended coil and a fixed magnet. In alternating-current galvanometers, the instrument may be made by suspending, within a coil of insulated wire, a needle of soft iron placed with its axis at an angle of 45 degrees to the axis of the coil. When an alternating current passes through the coil, the soft iron needle has a tendency to place itself in the direction of the axis of the coil. Other types have also been devised. A

ballistic galvanometer has its movable parts damped as little as possible, so as to make it adaptable for quick measurements, such as electric charges or discharges. The deflection is, therefore, proportional to the quantity of electricity rather than to the current.

Gang Drilling Machine. Some drilling machines equipped with multiple spindles are known as *gang drills*. The term "gang drill" is generally applied to a vertical design practically consisting of several machines combined in one unit, and with the spindles all in the same vertical plane. Machines of this general design are also referred to as multiple-spindle drills, by many manufacturers.

Gang Milling. A great deal of the work done on milling machines (especially the horizontal types) is machined by a combination or "gang" of two or more cutters mounted on one arbor. This is known as gang milling. If a plain cylindrical cutter were placed between two side mills a gang cutter would be formed for milling several surfaces. This would not only be a rapid method, but one conducive to uniformity when milling duplicate parts.

Gang or Multiple Dies. When large numbers of blanks are required, *multiple* or *gang dies* are sometimes used. These dies have a number of duplicate punches with similar openings in the die-block and cut as many blanks as there are punches, at each stroke of the press. The term "gang" die is often applied to a follow die; this usage is generally conceded to be incorrect, however, as the word "gang," as used in mechanics, ordinarily means a combination of similar tools so arranged as to act simultaneously for producing duplicate parts.

Gang Planing. When a number of duplicate parts have to be planed, much time can often be saved by arranging the castings in a straight row along the platen so that they can all be planed at the same time. This method, called gang planing, enables a number of parts to be finished more quickly than would be possible by machining them separately, and it also insures duplicate work.

Gang Presses. Power presses of the gang or multiple type are especially designed for operating long narrow dies requiring considerable power, such as those used for gang-punching rivet holes in sheets for boilers and tanks, riveting dies, corrugating and forming tools, etc. A typical press of the gang type has a gap frame and double-crank drive for the slide. The cam-actuated stripper is generally used in connection with these presses. This form of stripper permits the use of much shorter and more durable punches than can be employed with stationary strippers.

Moreover, the stripper comes down upon the metal and straightens it (if not too thick), holding it while punching and stripping takes place. After the punches have moved up through the sheet, the stripper also ascends.

Gang Presses of Double-action Type: These presses are designed for cutting, drawing, and stamping a large number of small shells at each stroke. They are equipped with several types of automatic feeds and operate very rapidly. Such presses are generally used for the manufacture of bottle caps and similar articles, when a large output is necessary. One type is provided with an automatic chain-feed, stripper, and an automatic sweep for the discharge of shells, and produces fourteen shells per stroke. It will handle sheets of decorative stock in such a way that the printed pattern will register accurately with the dies. The sheet is placed on the feed table, is automatically gripped, carried to the dies, and the bottle caps and scrap are automatically discharged separately.

Gantry Crane. This is a crane similar to a traveling crane except that the overhead bridge is carried at each end by a trestle which itself travels on longitudinal tracks on the ground. A trolley on the bridge provides for the transverse motion. Gantry cranes erected in shop yards alongside of a building are sometimes supported by an overhead rail at the end of the bridge next to the building and on a trestle traveling on the ground at the other end.

Gantt Bonus System. This is a method of wage payment in which the workman receives his regular daily wage irrespective of the amount of work done and, in addition, he receives a bonus which is some percentage of his hourly rate, if he performs a given job in a predetermined time. See Bonus Wage System.

Gap Presses. This type of power press is built with a gap or throat through the frame so that the stock can be fed from side to side or from front to back. With the exception of the gap, this type of press is similar to straight-sided or double-crank presses.

Garnet. The garnet is a natural abrasive that is extensively used in woodworking industries, in the manufacture of leather goods, and for other purposes. It is a mineral that varies widely in chemical composition and color. The variety most commonly used as an abrasive is known as "almandite," which is of a deep-red color. This color, however, changes as the material is broken into smaller particles, becoming lighter. Most of the garnet used for abrasive purposes in the United States is ob-

tained in New York state. The almandite garnet is found in the form of crystals in a gangue rock, from which it is separated by crushing and concentrating mechanically in a device known as a jig concentrator.

The hardness of garnet, according to Mohs's hardness scale, is about 7. According to this same scale, the diamond, which is the hardest substance, is represented by 10, while talc, which is the softest mineral, is represented by 1. Garnet seems to possess just the right degree of strength, hardness, and brittleness for cutting wood fiber and producing a smooth finish. Its brittleness insures new cutting edges being constantly presented to the work, and the cutting edges remain sharp, owing to its degree of hardness. As garnet has a low point of fusion, it is impossible to bond it in the form of wheels, except by using vegetable and silicate of soda bonds.

Gas Absorption by Liquids. Many liquids have a capacity for absorbing a certain amount of gas. The quantity thus absorbed varies with the liquid and the gas. Many gases, for example, are readily absorbed by water; thus, water will absorb its own volume of carbonic-acid gas, over two times its volume of chlorine, and 430 times its volume of ammonia. Water will not, however, absorb more than 5 per cent of its volume of oxygen. The weight of gas that a given volume of liquid will absorb is proportionate to the pressure, but as the volume of a given mass of gas is proportionately less as the pressure increases, the volume which a given amount of liquid will absorb at a certain temperature is constant, whatever the pressure. Water absorbs its own volume of carbonic-acid gas at atmospheric pressure. If the pressure is doubled on both the gas and water, the latter will still absorb its own volume of the gas under the higher pressure, but, in that case, the density of the gas is doubled and, consequently, double the weight of the gas is dissolved. The quantity of gas absorbed increases as the temperature is lowered. One of the most important instances of the absorption of gases by liquids is met with in the absorption of acetylene by acetone; the latter liquid absorbs, at 60 degrees F. and 180 pounds pressure per square inch, 300 volumes of acetylene gas. This property of acetone makes it possible to safely store and transport acetylene gas in steel containers.

Gas and Coal Fuel-Oil Equivalents. See Fuel Oil, Coal and Gas Equivalents.

Gas and Oil Engines. See Internal Combustion Engines.

Gas Coke. Gas coke is obtained as a by-product in gas works. This coke is produced rapidly at a low heat; it is of a dull black color and ignites readily.

Gas Furnace Fuel. Gas-fired furnaces use either natural, artificial, or producer gas. Some gas furnaces are equipped with an automatic apparatus which operates in conjunction with a pyrometer for controlling the temperature to within a few degrees of a given point. The air supply is generally obtained from a positive blower, although when a compressor is installed, for operating pneumatic tools, the air is sometimes utilized for the furnaces by interposing reducing valves to diminsh the pressure. Artificial gas is more expensive than oil, but is cleaner, and the installation of supply tanks, such as are required for oil, is avoided. Producer gas obtained from a separate plant is not economical unless there is a considerable number of furnaces; in that case, however, it may be the cheapest fuel obtainable. When oxidation or the formation of scale is particularly objectionable, furnaces of the muffle type are often used, having a refractory retort in which the steel is placed so as to exclude the products of combustion. These muffles must be replaced very frequently and more fuel is required than when an oven type of furnace is used.

Gas, Helium. See Helium Gas.

Gashing. The term "gashing" is used especially with relation to the cutting of the teeth in worm-gears. In this operation, a milling cutter is employed having approximately the outline of a normal cross-section of the teeth of the worm. Gashing is simply a roughing process preparatory to *hobbing* the gear teeth. After the gashing operation, the teeth are finished to conform to the exact shape of the worm by revolving the blank in unison with a cutter known as a *hob*, and which is practically a duplicate of the worm, but fluted and relieved so as to provide cutting teeth. This preliminary gashing operation is done when worm-gears are cut on ordinary milling machines but it is not required when using machines especially adapted for worm-gear cutting.

Gaskets for Joints. A gasket may be defined as a ring of some compressible material, inserted between two metallic surfaces which are to be tight against leakage of water, steam, or other liquid or gaseous fluid. The gasket forms a loose compressible film between the elements of the joint and, in this way, makes the joint leak-proof. Gaskets are usually made of sheet rubber (or rubber in combination with some other substance, such

as asbestos or graphite), sheet copper, sheet lead, cork, and paper. When the steam pressures are comparatively high, ordinary rubber gaskets are liable to be injured by the heat and, in such cases, copper or lead is frequently used. Gaskets containing rubber should not be used in the joints of gasoline engines or in gasoline supply piping, because rubber is slightly soluble in gasoline. For pipes which convey gasoline, it is better to use unions which have ground joints instead of joints made by gaskets. Gasket material composed largely of brass wire gauze and asbestos is frequently used, and, if properly fitted and provided with graphite facing, such gaskets are very durable.

Gasoline. Gasoline is a refined petroleum naphtha which by its composition is suitable for use as a carburant in internal combustion engines. The general refineries' practice is to call everything gasoline which distills up to a temperature of 410 degrees F. The specific gravity may vary from 54 degrees Baume for heavy crude oils up to 61 degrees for unusually light crude oil. A heavy gasoline must be blended to make it satisfactory for general use. The initial boiling point of ordinary commercial gasoline varies from 80 degrees F. to 160 degrees F.; the end boiling point, from 368 degrees F. to 450 degrees F., and the specific gravity from 56 degrees to 61 degrees Baume. Gasoline contains 129,060 British thermal units per gallon, or 20,750 per pound. The freezing temperature is 50 degrees F. below zero. Gasoline readily vaporizes when exposed to the air of any temperature down to 15 degrees F. below zero. The vapor is nearly three times as heavy as air, and when mixed with the proper quantity of air becomes violently explosive. If confined where there is poor ventilation, this mixture will sometimes remain in the explosive condition for several months. The vapor will ignite from an open flame, a spark from a grinding wheel or from a sufficiently heated surface.

Gasoline Cracking Process. See Cracking Process.

Gas Producers. The gas producer is an apparatus for the manufacture of combustible gas from solid fuel. Briefly described, it consists of a space enclosed by refractory materials and containing solid fuel (coal, coke, wood, or peat) at a high temperature, through which air and steam are caused to pass. The reaction between the air and steam and the fuel, which latter consists largely of carbon, causes the formation of hydrogen and carbon monoxide. These two combustible gases, mixed with the inert nitrogen introduced by the air, form a gas known as "producer gas."

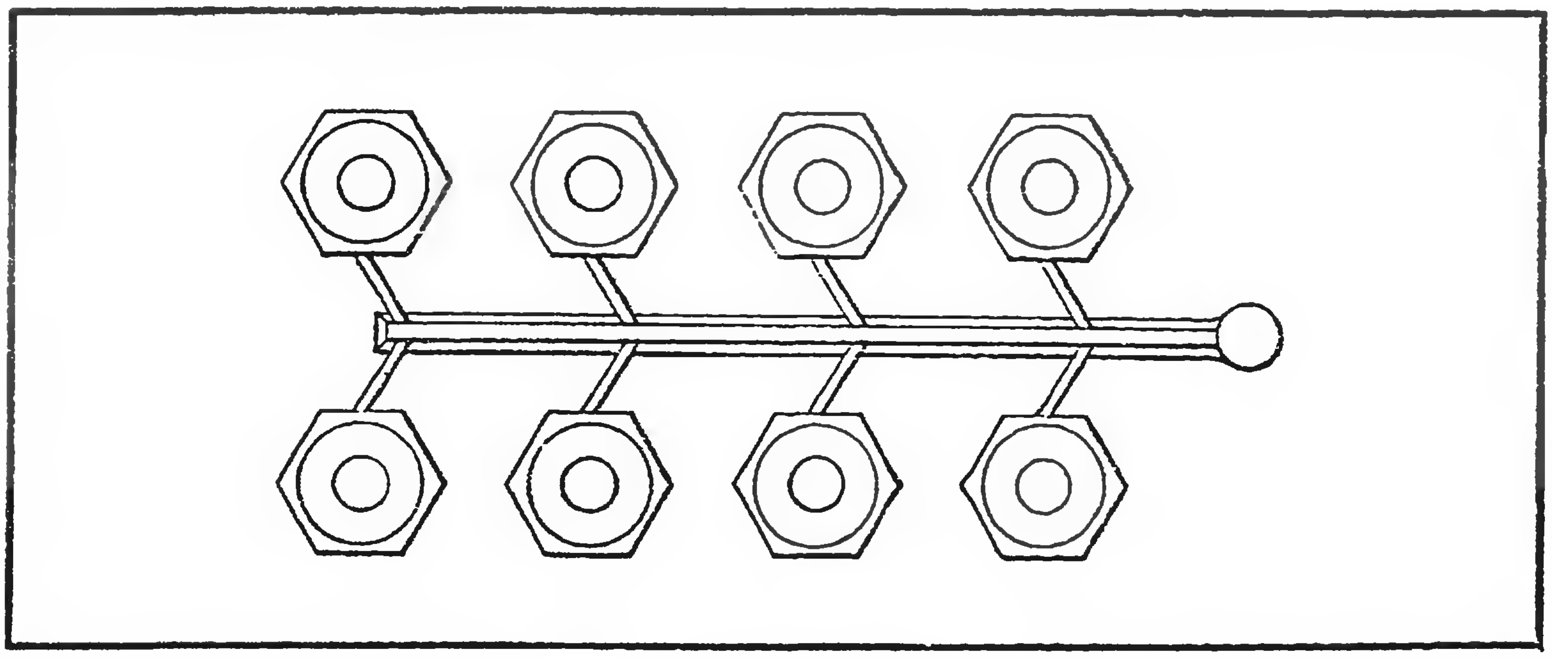
Gas producers are classified as "pressure producers" and "suction producers." In pressure producers, the air and steam are introduced into the producer at a pressure greater than that of the atmosphere, and the gas leaves the producer at a pressure slightly above the pressure of the outside air. In the suction producer, the air and steam are drawn into the producer by creating a partial vacuum in it, and the gas leaves the producer at a pressure lower than that of the atmosphere. Generally speaking, pressure producers are commonly used in metallurgical work, where the gas is employed for heating furnaces, since it is easier to handle and transmit the gas when it is at a pressure slightly above, rather than below, that of the atmosphere. Suction producers are used principally for furnishing the fuel gas for gas engines, because the gas is cleaner; the suction of the engine piston furnishes the necessary partial vacuum required for drawing from the producer the quantity of gas needed for the engine. The commercial designs of producers may be classified as five distinct types: The up-draft pressure type; the down-draft pressure type; the up-draft suction type; the down-draft suction type; and the combined up-and-down-draft suction type.

Gas Production. Manufactured gas may either be coal gas, water gas or oil gas. In producing *coal gas* certain kinds of bituminous coals are distilled in retorts or ovens and the resulting gases are condensed, scrubbed, washed and purified to remove water vapor, tar, ammonia and sulphur. *Water gas* is produced by an intermittent process in which a bed of anthracite coal or coke is raised to a high temperature by an air blast and then steam under pressure is blown through the fuel, forming carbon monoxide, hydrogen and a small amount of carbon dioxide by reaction with the carbon in the fuel. The so-called *blue water gas* thus obtained has a heating value of about 300 B.T.U. per cubic foot and almost no luminosity when burned in an open flame. "Mixed gas" is usually understood to be a mixture of carbureted water gas and coal or coke-oven gas, and it is supplied in many cities in the United States where requirements permit. Where oil is cheap and coal expensive, as on the Pacific Coast, oil gas is produced as it is more economical than the coal or water gases. In making oil gas, oil alone is used as fuel.

Natural Gas: Natural gas usually is associated with deposits of coal or petroleum and it is found trapped in various strata of the earth, principally in loose sandstone formations or in shale seams and cavities. Ordinarily natural gas is associated with petroleum and occupies the space above the oil in the petroleum-bearing sand. Occasionally gas is not accompanied by oil, in which case the gas composition is somewhat different.

Gas Pyrometers. In gas pyrometers, the change in pressure of a gaseous mass kept at a constant volume is used to indicate the temperature. Pyrometers based on this principle occupy considerable space and are not suitable for ordinary practical work. They are used only for standardizing other pyrometers.

Gas Turbine. A gas turbine is a rotary prime mover or power-producing machine in which the combustion gases of an explosive mixture of gas and air impinge at high pressure upon

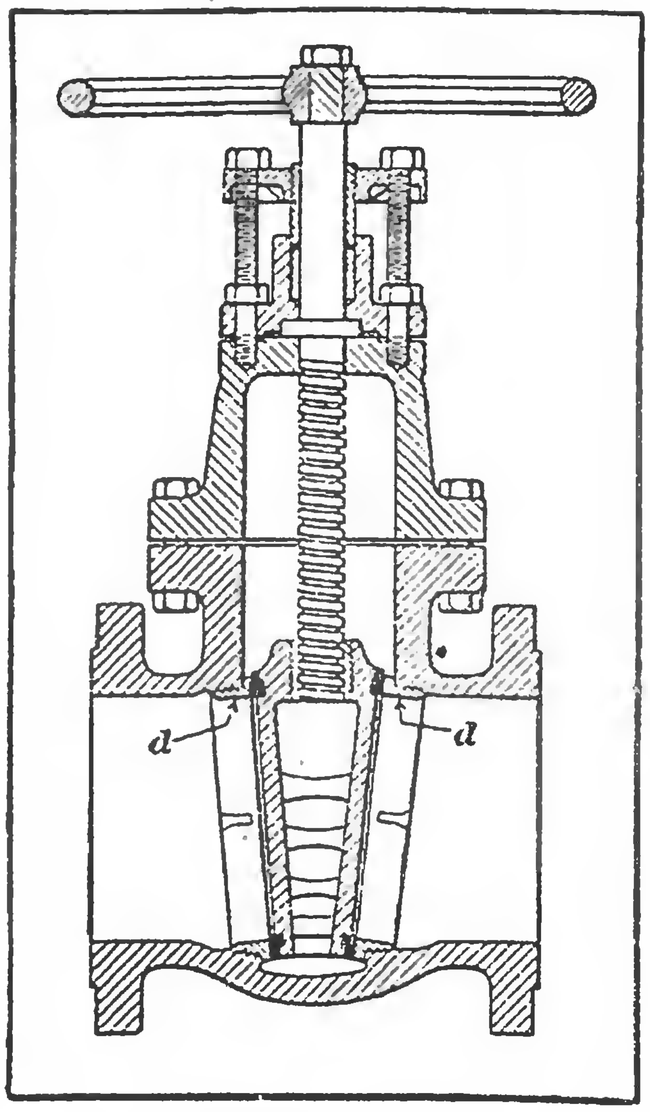


Gate of Hexagon Nuts

the blades of a turbine wheel or rotor in a manner similar to that in which steam impinges upon the blades of a steam turbine. Gas turbines are used as a component of jet aircraft engines.

Gas Welding. Gas welding is a process of fusing and uniting metals by the application of intense heat from a gas flame. Combinations of gases used are air-acetylene, oxy-acetylene, or oxy-hydrogen to obtain the required temperature. The gases are thoroughly mixed in a torch or blowpipe to insure perfect combustion which takes the place at the nozzle or tip. Ordinarily, the weld is formed by fusing-in additional material between the surfaces of the joint, which material is in the form of a rod or wire, and may or may not be of the same composition as the material being welded.

Gated Patterns. Where large numbers of small castings are required, it is more economical to make metal patterns and mount them on a gate. This means that a number of patterns are fastened to a pattern that forms the opening for pouring the metal and the channels for conveying it to the individual molds. The illustration shows a "gate" of hexagon nuts.



Gate Valve

Gate Valves. A gate valve, as its name implies is constructed on the principle of a gate, which is raised or lowered by the action of a screw or other mechanical means. Several forms of gate valves are used; some close the valve opening with a box wedge, others with sectional gates having seats parallel or wedge-shaped, and still others with gates formed like a solid wedge. One of the principal advantages in the use of a gate valve is that the opening is such that it does not obstruct the flow of liquid to any great extent. Valves of this kind are particularly desirable when the resistance to the flow of liquid should be as small as possible. Some gate valves are so made that the stem which raises the valve is threaded at its upper end, and passes up through the hub of the handwheel. In the form shown (see illustration), the stem is threaded at its lower end and enters a nut in the upper part of the wedge-shaped valve gate. The seat in the body of the valve is formed by rings which are inserted in both the gate and body, as indicated at *d* in the illustration. These rings are in each case made of soft metal, and are firmly imbedded and then faced off in such a way that the tapers coincide.

Gear Castings, Bronze. The following recommended practice for bronze and brass castings for gears, has been approved by the American Gear Manufacturers' Association.

For *spur and bevel gears,* use the hard cast bronze S.A.E. No. 62 or the well-known 88-10-2 mixture, keeping within the following limits: Copper, 86 to 89 per cent; tin, 9 to 11 per cent; zinc, 1 to 3 per cent; lead (maximum), 0.20 per cent; iron (maximum), 0.06 per cent. Good castings made from this bronze should give the following minimum physical characteristics: Ultimate strength, 30,000 pounds per square inch; yield point, 15,000 pounds per square inch; elongation in 2 inches, 14 per cent.

For *bronze worm-gears,* two alternative analyses of phosphor-bronze are recommended, namely, S.A.E. No. 65 and No. 63. The S.A.E. No. 65, called phosphor-gear bronze, has the following composition: Copper, 88 to 90 per cent; tin, 10 to 12 per cent; phosphorus, 0.1 to 0.3 per cent; lead, zinc, and impurities (maximum),

0.5 per cent. Good castings made from this alloy should give the following minimum physical characteristics: Ultimate strength, 35,000 pounds per square inch; yield point, 20,000 pounds per square inch; elongation in 2 inches, 10 per cent.

Composition for the S.A.E. No. 63 alloy, called leaded gun metal, is: Copper, 86 to 89 per cent; tin, 9 to 11 per cent; lead, 1 to 2.5 per cent; phosphorus (maximum), 0.25 per cent; zinc and impurities (maximum), 0.50 per cent. Good castings made of this alloy should give the following minimum physical characteristics: Ultimate strength, 30,000 pounds per square inch; yield point, 12,000 pounds per square inch; elongation in 2 inches, 10 per cent.

These alloys, especially No. 65, can be chilled for increasing the hardness and refining the grain. No. 65 is to be preferred for use with worms of great hardness and fine accuracy. No. 63 is to be preferred for use with unhardened worms.

For bronze *bushings for gears*, S.A.E. No. 64 is recommended, having the following analysis: Copper, 78.5 to 81.5 per cent; tin, 9 to 11 per cent; lead, 9 to 11 per cent; phosphorus, 0.05 to 0.25 per cent; zinc (maximum), 0.75 per cent; other impurities (maximum), 0.25 per cent. Good castings of this alloy should give the following minimum physical characteristics: Ultimate strength, 25,000 pounds per square inch; yield point, 12,000 pounds per square inch; elongation in 2 inches, 8 per cent. See English Gear Bronze; also Phosphor-Bronze.

Gear-Chucking Methods. The followng methods are employed for holding gears while grinding the shaft holes: (1) Holding the gear by the outside diameter or tops of the teeth. (2) Using rolls between the teeth—sometimes called the "pitch-line control method." (3) Using jaws of special shape, which make contact with the gear at the bottom of the tooth spaces—a method known as "root control." The first method cannot be used with success when the gears are to run at high speeds, because of the possible lack of concentricity between the hole and the working surfaces of the teeth. The second method, while requiring the use of a more expensive chuck, is much more satisfactory than the first, provided the spacing of the teeth has not been affected by hardening and the rolls are uniform in diameter and supported by a truly concentric surface. A slight variation in the width of the tooth spaces, however, makes a considerable difference in the relative position of the rolls, owing to the acute angle made by the tooth surfaces near the pitch line where the rolls bear. This has been considered, by some manufacturers, a serious objection to this method. For the average line of work, the third method is recommended. The jaws of the chuck engage the

bottom of the tooth spaces, so that inaccuracies of spacing, due to hardening the teeth, do not affect the accurate holding of the gear; furthermore, it is a very simple matter to maintain the accuracy of the jaws by simply truing the contact points whenever necessary.

Gear-Cutters. The series of formed cutters ordinarily used for cutting spur gears contains eight cutters for each pitch. These eight cutters are adapted to cut all gearing from a pinion of twelve teeth to a rack. Each cutter may be used for a limited range of tooth numbers. The number of teeth and the pitch for which a cutter is adapted are always marked on the cutter. These cutters are numbered from 1 to 8 and the different numbers are adapted for spur gears of the following sizes: Cutter No. 1, for gears having teeth varying from 135 to a rack; No. 2, gears with from 55 to 134 teeth; No. 3, from 35 to 54 teeth; No. 4, from 26 to 34 teeth; No. 5, from 21 to 25 teeth; No. 6, from 17 to 20 teeth; No. 7, from 14 to 16 teeth; and No. 8, from 12 to 13 teeth. If it is assumed that the diametral pitch of the gear to be cut is 12, and the required number of teeth, 90, a No. 2 cutter of 12 diametral pitch would be used, the No. 2 shape being selected because it is intended for all gears having teeth varying from 55 to 134.

Intermediate Series: When greater accuracy of tooth shape is desired to insure smoother or quieter operation, an intermediate series of cutters having half numbers is used. The half numbered cutters made by the Brown & Sharpe Mfg. Co., are for the following ranges of tooth numbers: Cutter No. 1½, 80 to 134 teeth; No. 2½, 42 to 54; No. 3½, 30 to 34; No. 4½, 23 to 25; No. 5½, 19 and 20; No. 6½, 15 and 16; and No. 7½, 13 teeth. There are seven cutters in this series, No. 8½ being omitted since this would be for a pinion with less than 12 teeth.

Gear-Cutting Attachment. When it is necessary to cut comparatively large spur gears on a milling machine, a gear-cutting attachment is preferable to the regular dividing-head. This attachment, in its usual form, is similar to a dividing-head, but is larger and heavier in construction. If the gear is too large to clear the machine table when mounted between the centers, the centers are sometimes raised far enough to provide clearance for the gear blank by placing parallel blocks underneath the index-head and tail-center. If the gear blank is so large that it will not pass under the cutter arbor with the table in its lowest position, it may be possible to cut the gear by using an "under-cutting attachment." The centers are raised far enough to provide room for the cutter beneath the gear, and the arbor is supported by a special outboard bearing.

Gear-Cutting Processes. The gear-cutting processes commonly utilized for producing different types of gears may be divided into three general classes. One includes the use of tools or cutters which form gear teeth by reproducing the shape of the cutter itself; in another class are the generating processes whereby the proper tooth curves are formed through relative motions of the tool and work, as when a straight-sided cutting tool generates the required tooth curves due to the relative motions imparted to the gear blank and cutter. The third general classification includes the use of templets or master formers, which control the path followed by the cutting tool, and consequently the curvature of the gear tooth; this method is applied chiefly to the cutting of very large gears.

In the application of these processes the gear teeth may be formed by (1) milling the teeth with cutters conforming to the shape of the spaces between the teeth; (2) milling the teeth with a cutter of the hob type, which represents a rack in the axial plane and is used in generating the tooth curves; (3) planing with a circular cutter which has teeth like a gear and serves to generate the tooth curves as the cutter and gear blank revolve in unison; (4) planing with a tool that takes a series of cuts across the side of the tooth and is guided by a templet or former as it is gradually fed inward; (5) planing with a tool that conforms to a single rack tooth and generates the tooth curves as it moves laterally after each stroke, while the gear blank receives an indexing movement that causes each tooth to mesh properly with the traversing tool; (6) planing with a tool which is similar to a short section of a rack and is used in generating tooth curves as the gear blank rotates relative to the rack cutter; and (7) planing the teeth of the gear by the use of a formed tool which is of the same shape as the tooth spaces. See following paragraphs on gear-cutting processes and machines; also Automatic Gear-cutting Machines; Bevel Gear Generating Processes; Hobbing Process.

Gear Cutting by Generating Process: In order to illustrate the principle of the generating process of gear-cutting, assume that a finished spur gear having teeth of correct form is revolved while in contact with a blank, which for purposes of illustration is assumed to be made of some soft, plastic material. The nature of this rolling action would be to generate teeth on the plastic blank. Thus, the teeth on the finished gear, as they roll into contact with the blank, form teeth having the curvature required for meshing properly with the generating teeth. Now, if this tooth forming or generating gear were hardened, and its teeth given suitable clearance, the cutter thus formed could be used to generate teeth in a cast-iron or steel blank, provided the cutter

had a reciprocating action parallel to the axis of the blank, while both cutter and blank slowly revolved together, the same as two gears in mesh. This method of using a gear-shaped cutter is employed on a well-known type of machine.

Another method of generating gear teeth is to give the gear blank a rolling movement relative to a rack-shaped cutter. It is possible to employ either a gear-shaped or a rack-shaped cutter, because a rack can be designed, for any system of interchangeable gearing, which will mesh correctly with a range of gear sizes of the same pitch. Moreover, all gears that will mesh properly with the rack will also mesh with one another. Generating processes of cutting gears are based on this interchangeable feature, which also accounts for the fact that one cutter may be used for cutting various sizes of gears of the same pitch. The cutter represents either a rack or a gear of the interchangeable series, and it cuts or generates teeth as the uncut gear blank and cutter are given movements, relative to each other, similar to a finished gear running in mesh either with a rack or with another gear, depending upon the type of cutter that is used. See also Bevel Gear Generating Processes.

Gear-Finishing Machines. When very precise gears are required as in the automotive, aircraft, and certain other industries, special gear-tooth finishing machines are used. There are several different types. One type (which is used extensively) takes a very light shaving cut to correct errors left by the gear-cutting machine. The general practice is to semi-finish the gears on some generating type of gear cutter and then use a finishing machine. A lapping operation may also be applied to gears which, prior to heat-treatment, were finished on a machine of the shaving type. This dual finishing process is applied when extreme precision is essential. A third type of gear-finishing machine operates by rolling the gear to be finished in contact with a master burnishing gear. In using a shaving type of machine, the cutting action may also be accompanied by more or less burnishing, depending upon the angular position of the cutting tool as explained later. A fourth general method of finishing gears, especially after hardening, is by grinding. Finishing methods have been developed for different classes of gears, such as external and internal spur and helical gears, bevel gears, spiral-bevel gears, and hypoid gears.

Rotary Gear-Shaped Type of Finishing Cutter: A common type of machine for finishing by taking a light shaving cut is equipped with a cutter having either helical or spur teeth. Shaving tools of the spur type may be used for helical gears up to 15 degrees helix angle, and the helical type of shaving tool for larger helix

angles. The faces of the cutter teeth have closely spaced grooves separated by narrow lands to form a number of cutting edges. This cutter meshes with and rotates the gear to be finished, and this rotation is accompanied by a longitudinal motion to bring the entire face of each gear tooth in contact with the cutter. The angular position of the cutter is adjustable and the axes of the cutter and gear lie in planes which intersect, usually at angles of 10 to 15 degrees. This *crossed axis* method is important not only in gear-tooth shaving, but also in finishing by lapping. The angularity is conducive to greater accuracy because of the increased guiding action between cutter and work and a better cutting action due to improved clearance for the cutting edges. As the angle is reduced below 10 degrees, the shaving or cutting will be accompanied by increased burnishing action. When the angle is zero, this is known as the *parallel axis method.* This may be employed to prevent interference with a shoulder, but it is preferable to use the crossed-axis method whenever possible. When the cutter axis is parallel or nearly so, much greater contact pressure is required which explains the increase in burnishing action.

In finishing a gear, there is a longitudinal reciprocating movement and also a feeding movement to bring the cutter and gear closer together for removing the required amount of metal. The reciprocating movement is equal to or slightly greater than the face width of the gear being finished. Each reversal is accompanied by a reversal of cutter rotation, so that both faces of each tooth are in contact with the cutter during each cycle. After each cycle, an automatic feeding movement of possibly 0.001 to 0.003 inch occurs until the machine is stopped automatically after a predetermined number of cycles.

Rack Method of Crossed-Axis Gear-Tooth Shaving: With this method, the teeth of a semi-finished gear are accurately generated while in mesh with a reciprocating rack-shaped cutter made to conform with the basic rack of the gear to be finished. The faces of the rack teeth have narrow parallel grooves with intervening lands which form the cutting edges. The gear to be finished is mounted upon centers and meshes with the rack which is given a reciprocating movement like a planer table. Racks of the straight type may be used for helical gears up to 30 degrees helix angle. For larger angles, an angular rack must be used—either right- or left-hand, as required. The gear-holding head is swiveled so that the angle between the gear axis and rack equals the helix angle (unless this angle exceeds 30 to 33 degrees). Since the plane of the rack's movement is at an angle to the gear axis, the result is a shaving action due to the crossed-axis relation between the rack and work. There is a cross-feed to reciprocate the

gear across the rack and a down-feed for removing enough metal for finishing. The various movements are stopped automatically after a predetermined number of finishing strokes. This type of machine is especially adapted to mass production.

Finishing Gears by Lapping: The lapping process is an inexpensive method of correcting the slight errors which may be caused in hardening finished gears. Lapping may be described as a refining process. The lap (or laps) resembles a gear. For example, the type of lap used for helical gearing also has helical teeth. Some machines have a single lap; others, two laps; and a third type, three laps. The lap (or laps) rotates with the gear, and a lapping compound is applied by brush or pump. The crossed-axis principle is applied in lapping as in finishing by the shaving method.

A Michigan two-lap type of machine is designed to hold the work on centers and between front and rear laps. The machine has a relatively low surface speed of rotation with a high reciprocating speed of the laps across the gear face. The lap-spindle heads are adjustable to provide the correct amount of crossed-axis adjustment (lap angle minus gear angle). The machine is automatic in operation and the lapping cycle may be adjusted to meet requirements.

The Michigan three-lap type of machine not only accelerates the lapping operation, but permits lapping more at some portion of the tooth and less at other portions. This, for example, is done in "crowning" or when the major bearing is to be at the center of the tooth. The lapping cycle of this machine is under automatic control. See also Gear-tooth Grinding.

Gear-Hobbing Machines. Gear-hobbing machines are commonly applied to the cutting of spur, helical, and worm gearing. In the practical application of the generating principle to gear-hobbing machines, the hob used has cutting teeth of the same cross-sectional shape as teeth of a rack of corresponding pitch, except for minor variations such, for example, as increasing the length of the hob teeth to provide for clearance at the bottom of the tooth spaces. As the hob teeth lie along a helical path (like a screw thread) the hob is set at an angle to align the teeth on the cutting side with the axis of the gear blank. When the hob is inclined an amount depending upon its helix angle the teeth on the cutting side represent a rack.

When a hobbing machine is in operation, the gear blank and hob revolve together, the ratio depending upon the number of teeth in the gear and the number of threads on the hob—that is, whether the hob has a single or a multiple thread. This rotation of the hob causes successive teeth to occupy positions correspond-

ing to the teeth of a rack, assuming that the latter were in mesh with the revolving gear and moving tangentially. In conjunction with the rotary movement of the hob, the slide on which it is carried is given a feeding movement parallel to the axis of the gear blank.

Gear Planers of Templet Type. Large spur gears of coarse pitch may be cut either by planing on a templet or form-copying type of machine, by milling with a formed cutter, or by hobbing. Most gear manufacturers use the templet planer for the very large gears. One advantage of this type of machine is that simple, inexpensive tools are used, and this is very important, as often only one of these large gears is required, and the cost of making a formed cutter or hob would be prohibitive. Gear-cutting machines of the templet type are also used for cutting large spur, bevel, and herringbone gears; in fact, gear planers of this class are used invariably for cutting very large bevel gears. Some gear planers are designed for cutting spur gears exclusively, but there are also combination types which may be applied to either spur or bevel gears.

A characteristic feature of the templet planer is the templet or master former which serves to guide the planing tool, thus causing it to plane teeth having the correct shape or curvature. When the planer is at work, a slide or head which carries the tool is given a reciprocating motion, and as the tool feeds inward for each stroke, the path it follows is controlled by the templet. The traversing movement of the tool-slide is derived from a crank on some gear planers, whereas others have a reversing screw. Still another method of traversing the head is by means of a rack and pinion, the latter being arranged to rotate in opposite directions.

Gear Shaper. The Fellows gear shaper is a machine of the generating type which operates with a shaping or planing action to generate gear teeth. The cutter has tooth outlines conforming to a gear of the same pitch as the ones being cut. This cutter is reciprocated vertically, and in starting to cut a gear it is first fed in to depth; then one gear tooth after another is formed as cutter and work slowly rotate together just as though two finished gears were in mesh. The gear blank is withdrawn from the cutter upon the return stroke to prevent dragging, the work-arbor being held by an apron actuated by a relieving mechanism. The gear teeth can be finished in one revolution of the gear blank, although a light finishing cut is often taken. In cutting transmission gears for automobiles, it is common practice to take a roughing cut followed by a light finishing cut. The machine may be arranged to take these two cuts automatically, but when gears are required on a large scale, it is generally considered preferable to use certain machines for roughing and others for finishing.

Gears, Non-Metallic. Non-metallic gears are used primarily where quietness of operation at high speed is the first consideration. Rawhide was the earliest material used for this class of gearing; later numerous other materials such as micarta, formica, condensite, fabrico, fabroil, and Egyptian fiber were introduced. These materials are used by many gear manufacturers when the gears are not subjected to severe stresses.

Gears, Ratios in Speed-Changing Mechanisms. See under Speed-Changing Mechanisms.

Gears, Rolled. A method of cold roll-forming external gears and splines developed by Grob, Inc., Grafton, Wis. In this process, a pair of identical, opposed, planetary rollers repeatedly and simultaneously contact a cylindrical blank. The blank is either continuously rotated or indexed to expose all grooves to rolling, in timed relation with the rollers, which travel to and from the blanks on rotor carriers. The blank is also fed axially between the rollers. Each forming roller is free to rotate about its own axis. With this combination of rotation (or indexing) and feed, the required gear or spline teeth are progressively formed both around the periphery and parallel to the axis of the blank as seen in Fig. 1. Each successive engagement of the rollers with the blank is deeper until final penetration is reached. Forming is completed in a single pass of the blank.

The rollers used for a particular set-up are identical in shape, as shown in Fig. 2 and each has one forming rib and an auxiliary rib. The forming rib corresponds with the shape of the groove to be formed. The auxiliary rib is used to contact the previously finish-rolled, adjacent groove whenever possible, as seen in Fig. 3, to insure accurate tooth spacing. The auxiliary rib is also used to support the tooth against bending if the tooth is relatively high. The use of two opposed rollers balances the pressure exerted on the blank. However, a single roller could be used if the blank were properly supported. More than one pair can be used, but, in most cases, there is no advantage. The planetary rollers "squeeze" the blank during only a short part of their cycle, and do not contact the blank during the greater part of their cycle. In cases where the blank is indexed, indexing of one tooth space is done while the rollers are out of contact with the blank. Thus, the next groove is formed by the next contact of the rollers, at which time rotation of the blank is stopped.

As the blank is fed longitudinally, the rolls penetrate successively deeper into the blank. When the two planetary rollers are at a minimum distance from each other—called "dead center"—the blank is penetrated to full depth at that point. Maxi-

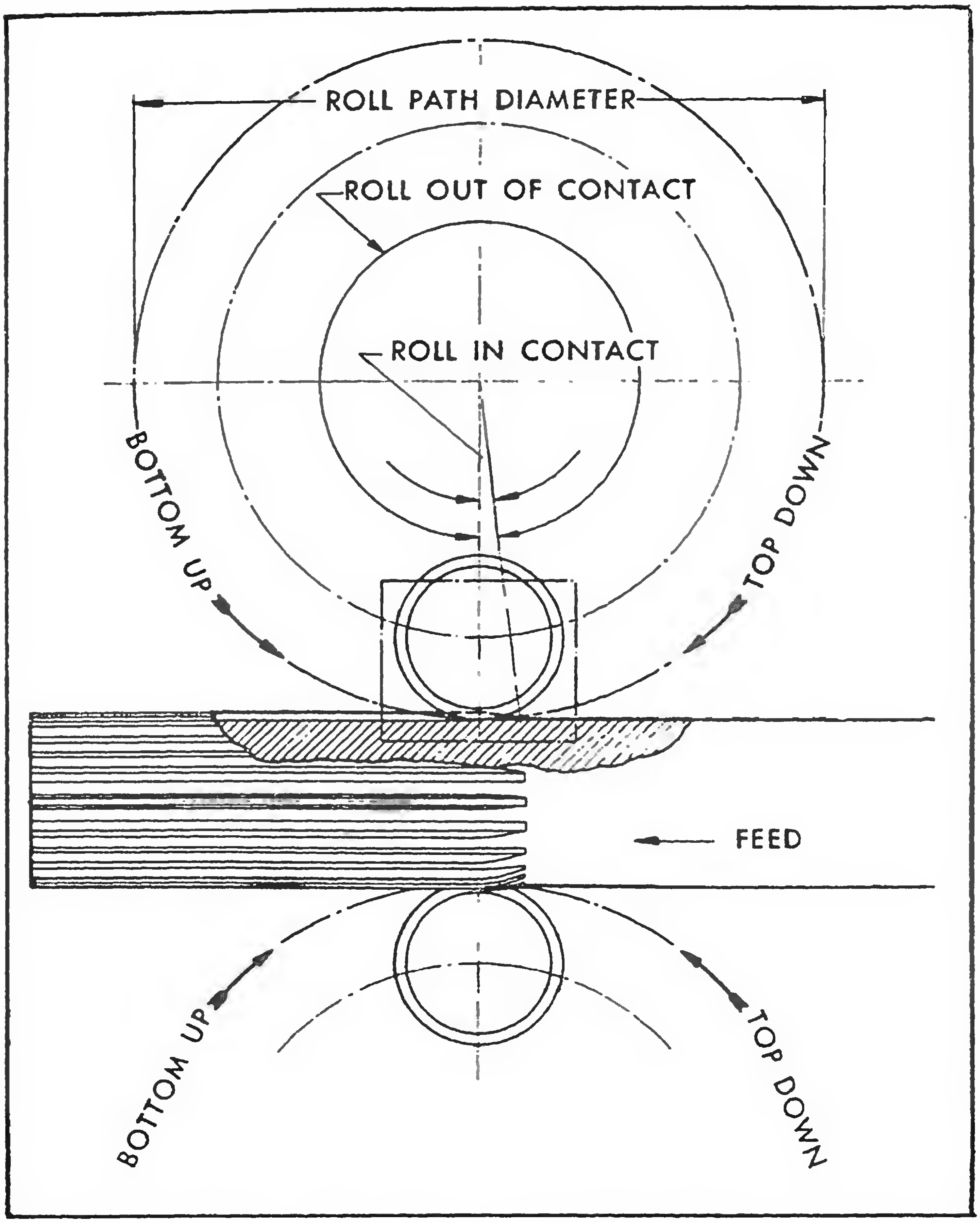


Fig. 1. Opposed Rollers Repeatedly and Simultaneously Contact Cylindrical Blank which is Rotated (or Indexed) and Fed between the Rollers to Progressively Form Splines or Gears

mum penetration of the rollers with the work per feeding increment (roughing) occurs during initial contact in a specific area, and minimum penetration per feeding increment (finishing), at dead center or last contact in that same area. The dead center distance is predetermined, and is not varied while the machine is in operation. Also, longitudinal feed of the blank between the rollers is at a constant rate. A part requiring *X* number of splines or gear spaces makes one revolution (or is indexed once)

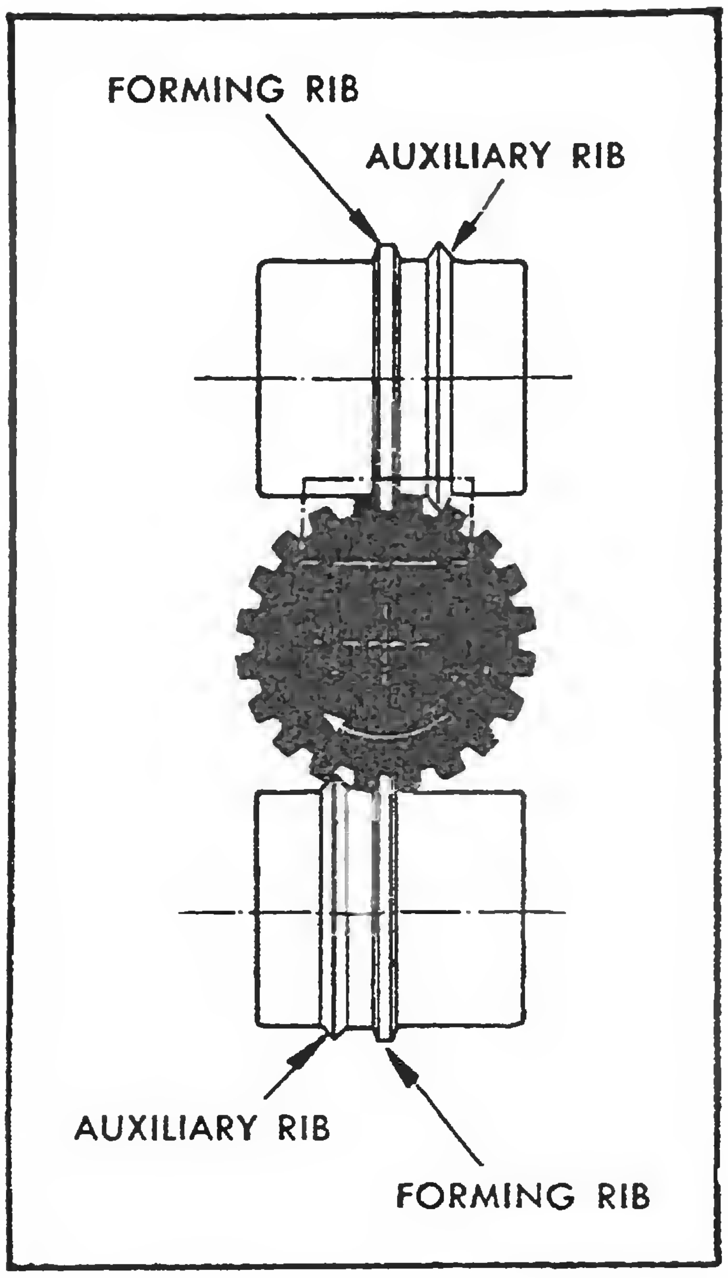


Fig. 2. The Pair of Identical Rollers used in Cold Forming Splines or Gears each have One Forming Rib and an Auxiliary Rib

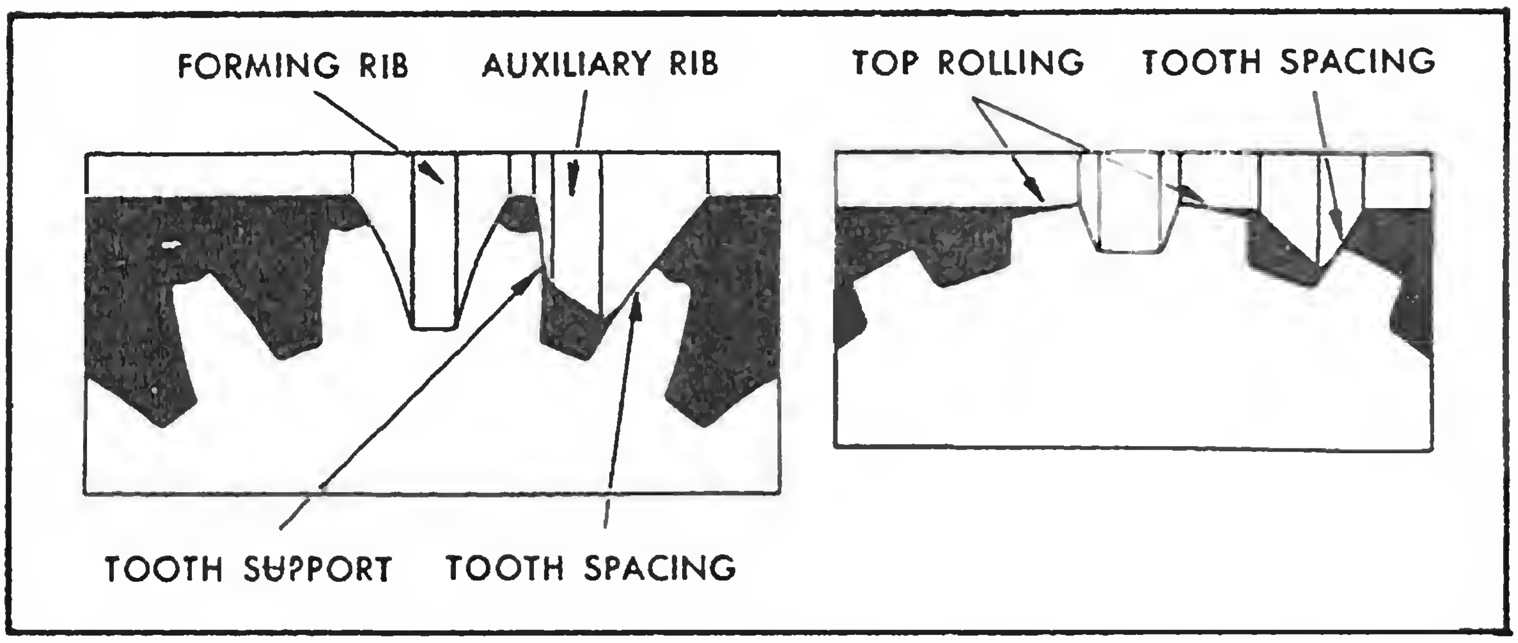


Fig. 3. Forming Ribs on Rollers have Shape of Grooves to be Formed, and Auxiliary Ribs Insure Accurate Spacing and may Support Teeth against Bending

while the rollers cycle (make contact with the workpiece) X times.

Indexing of rotation of the blank can be either in a clockwise or counter-clockwise direction. As a result, the planetary rollers contact the work from the "top down" or the "bottom

up" (Fig. 1), but they must always oppose each other in exact timed relation.

As can be seen from Fig. 1 the groove is being rolled from the "bottom up" when the rotation of the roller is against the direction of longitudinal feed. When its rotation is with the longitudinal feed the rolling action is "top down." Depending on the application, the rollers cycle between 800 and 3500 times per minute.

Continuous rotation of the blank should be employed whenever possible, since this eliminates the acceleration or deceleration problems encountered when the blank is intermittently indexed. However, rotary speeds are limited by those available on the machine—which vary from 1800 to 3500 rpm, depending on the size and design of the workpiece. Relatively large roller paths, as well as shallow roller ribs with adequate side angles (or draft), are more suitable.

When the blank continues rotating while the rollers are in contact with the work, a slight "twist" occurs between the finish-rolled and rough-rolled areas. This "twist" increases when the workpiece requires fewer grooves, if the roller path diameter is smaller, or if the forming ribs are higher. To align the rough- and finish-rolled grooves, it is necessary to swivel the roller rotor axis with relation to the work axis.

"Twist" does not exist, nor is it necessary to swivel the rotor axis, when the blank is intermittently indexed—stopping the rotation of the blank while it is in contact with the rollers. For this reason, interrupted rotation of the blank is advisable when rolling highly precise gears, and necessary when producing parts requiring a low number of splines or gear tooth spaces. This technique is also necessary if relatively small roller-path diameters and deep forming teeth are used. Production is slower with this method, the reduction in output depending upon the number of times the blank rotation must be stopped and started. With present machines, this can be accomplished 800 to 1200 times per minute—the exact number depending on the number of teeth or splines and the size of the part.

As the grooves between the teeth or splines are successively and repeatedly deepened, the teeth or splines increase in height. The best growth is obtained if the tooth or spline is contacted on only one side at a time. If contacted on both sides, the confining action interferes with growth. Plastic flow of the metal should not reach the center of the blank, as this will cause uncontrollable longitudinal flow. The fewer the number of teeth or splines to be rolled on a blank, the smaller the undisturbed area becomes. Trouble may be encountered in rolling parts with less than ten teeth if the normal feed rate is used. However, with relatively narrow spaces between the teeth and a reduced

feed rate, gears with as few as six teeth can be rolled. Tubular blanks must have sufficient wall thickness and fine enough teeth to permit successful rolling. Less collapsing will be experienced in rolling tubular blanks if the roller and roller path diameters are small and the feed rate slow.

It is essential to force the material between adjacent teeth downward (toward the center of the blank). For this reason, grooves having wide, flat bottoms are more suitable for rolling than narrow grooves. With flat bottoms, the material flows toward the tooth crowns from more adjacent areas, "rabbit ear" effects on the tooth crown are minimized, and better teeth with improved grain structure are obtained.

Practically any ductile material may be rolled. However, materials as soft as lead do not have enough internal resistance to plastic deformation to permit satisfactory rolling, and hardened steel does not flow well. The blanks should have uniform ductility and shape to produce accurate parts. Since there is no reduction in volume during rolling, tolerances maintained on the blanks affect those held on the finished part. Top rolling, illustrated at the right in Fig. 3, can only be attempted if the blank diameters are kept extremely accurate and the tooth crowns are not too narrow. Variations in the blank diameters will result in relatively increased variations in the height of the tooth crown. Also, the narrower the tooth crown, the greater this variation.

Accuracies obtained are usually considerably better than those achieved by machining, and are generally almost as good, and sometimes better, than those by grinding. The fine surface finish produced is typical of those produced in cold-working. Increased strength results from the cold-working and work-hardening. A part rolled from annealed steel is invariably stronger than a comparative part machined from the same material but hardened before machining. Distortion in heat-treating rolled parts is considerably less because the grain structure has been rearranged in a uniform pattern conforming with the teeth.

Gear Steels. Gear steels may be divided into two general classes—the plain carbon and the alloy steels. Alloy steels are used to some extent in the industrial field, but heat-treated plain carbon steels are far more common. The use of untreated alloy steels for gears is seldom, if ever, justified, and then, only when heat-treating facilities are lacking. The points to be considered in determining whether to use heat-treated plain carbon steels or heat-treated alloy steels are: Does the service condition or design require the superior characteristics of the alloy steels, or, if alloy steels are not required, will the advantages to be derived offset the additional cost? For most applications, plain carbon steels, heat-treated to obtain the best of their qualities for the service

intended, are satisfactory and quite economical. The advantages obtained from using heat-treated alloy steels in place of heat-treated plain carbon steels are as follows:

1. Increased surface hardness and depth of hardness penetration for the same carbon content and quench.

2. Ability to obtain the same surface hardness with a less drastic quench and, in the case of some of the alloys, a lower quenching temperature, thus giving less distortion.

3. Increased toughness, as indicated by the higher values of yield point, elongation, and reduction of area.

4. Finer grain size, with the resulting higher impact toughness and increased wear resistance.

5. In the case of some of the alloys, better machining qualities or the possibility of machining at higher hardnesses.

Gear Steels, Casehardening. Each of the two general classes of gear steels may be further subdivided as follows: (1) Casehardening steels; (2) full-hardening steels; and (3) steels that are heat-treated and drawn to a hardness that will permit machining. The first two—casehardening and full-hardening steels—are interchangeable for some kinds of service, and the choice is often a matter of personal opinion. Casehardening steels with their extremely hard, fine-grained (when properly treated) case and comparatively soft and ductile core are generally used when resistance to wear is desired. Casehardening alloy steels have a fairly tough core, but not as tough as that of the full-hardening steels. In order to realize the greatest benefits from the core properties, casehardened steels should be double-quenched. This is particularly true of the alloy steels, because the benefits derived from their use seldom justify the additional expense, unless the core is refined and toughened by a second quench. The penalty that must be paid for the additional refinement is increased distortion, which may be excessive if the shape or design is not all that it might be.

S.A.E. Steels for Casehardening: These steels for the higher classes of service, include nickel steel No. 2317 (old No. 2315); nickel-chromium steels 3115, 3120, 3310 (old No. 3312); and molybdenum steels 4119, 4125, 4320, 4615, 4620, 4815, and 4820. Engineering handbooks give the physical properties, the heat-treatment, and general information about specific applications of these various carburizing steels.

Gear Steels, "Full-Hardening." Full-hardening steels are used when great strength, high endurance limit, toughness, and resistance to shock are required. These qualities are governed by the kind of steel and treatment used. Fairly high surface hardnesses are obtainable in this group, though not so high as those of the casehardening steels. For that reason, the resistance to

wear is not so great as might be obtained, but when wear resistance combined with great strength and toughness is required, this type of steel is superior to the others. Full-hardening steels become distorted to some extent when hardened, the amount depending upon the steel and quenching medium used. For that reason, full-hardening steels are not suitable for high-speed gearing where noise is a factor, or for gearing where accuracy is of paramount importance, except, of course, in cases where grinding of the teeth is practicable. The medium and high-carbon percentages require an oil quench, but a water quench may be necessary for the lower carbon contents, in order to obtain the highest physical properties and hardness. The distortion, however, will be greater with the water quench.

S A E Full-Hardening Steels: The S A E steels include carbon steel No. 1045, nickel-chromium steel No. 3145, chromium-vanadium steel No. 6145, and molybdenum steel No. 4150.

Gear Steels, Heat-Treatment after Machining. When the grinding of gear teeth is not practicable and a high degree of accuracy is required, hardened steels may be drawn or tempered to a hardness that will permit the cutting of the teeth. This treatment gives a highly refined structure, great toughness, and, in spite of the low hardness, excellent wearing qualities. The lower strength is somewhat compensated for by the elimination of the increment loads due to the impacts which are caused by inaccuracies. When steels that have a low degree of hardness penetration from surface to core are treated in this manner, the design cannot be based on the physical properties corresponding to the hardness at the surface. Since the physical properties are determined by the hardness, the drop in hardness from surface to core will give lower physical properties at the root of the tooth, where the stress is greatest. The quenching medium may be either oil, water, or brine, depending on the steel used and hardness penetration desired. The amount of distortion, of course, is immaterial, because the machining is done after heat-treating.

S A E Steels for Heat-Treatment After Machining: These include carbon steel No. 1045, nickel-chromium steel No. 3140, and molybdenum steel No. 4130.

Gears, Types. See Bevel Gear; Bevel Gears, Gleason System; Friction Gearing; Helical Gears; Herringbone Gears; Internal Gears; Maag Gearing; Spur Gearing.

Gear Teeth. See Cycloidal Gear Teeth; also Involute Gear Teeth.

Gear Teeth Invention. The invention of gear teeth cannot be credited to any one man, as their development represents a gradual evolution from gearing of primitive form. Gears were known to Archimedes who lived 287-212 B.C., according to Ctesi-

bius of Alexandria in his "History of Mathematics." Ctesibius first applied gears to the clepsydrae (water clocks) about 150 B.C. The knowledge and use of toothed wheels by the Romans early in the Christian era is indicated by the fact that they are shown sculptured on the Column of Trajan in Rome. Leonardo da Vinci showed an appreciation of the use of gearing, many applications of it in connection with mechanisms devised for widely varying purposes being found in the sketches that form a part of his "Codice Atlantico." This work illustrates the use of worm-gearing, and suggests a choice of two forms of teeth, one of the buttress type and the other in shape much like present-day practice.

The Cycloidal Form: The earliest evidence we have of an investigation of the problem of uniform motion for toothed gearing and the successful solution of that problem, dates from the time of Olaf Roemer, the celebrated Danish astronomer, who, in the year 1674, proposed the epicycloidal form to obtain uniform motion in trains of gearing. In 1766 Charles E. L. Camus, in his treatise "Cours de Mathematique," dealt with gearing. This treatise fully describes the epicycloidal curve in such a way as to make it for the first time available to some extent for practical application, and points out its advantages as applied to gearing. Camus deals only with the epicycloidal form of tooth, and emphasizes its application to clock and watch work. Evidently Robert Willis, professor in the University of Cambridge, was the first to make a practical application of the epicycloidal curve so as to provide for an interchangeable series of gears. Willis gives credit to Camus for conceiving the idea of interchangeable gears, but claims for himself its first application.

The Involute Form: The involute tooth was suggested as a theory by early scientists and mathematicians, but it remained for Willis to present it in a practical form for use by the manufacturing public. Perhaps the earliest conception of the application of this form of teeth to gears was by Philippe de Lahire, a Frenchman, who considered it, in theory, equally suitable with the epicycloidal for tooth outlines. This was about 1695 and not long after Roemer had first demonstrated the epicycloidal form. The applicability of the involute had been further elucidated by Leonard Euler, a Swiss mathematician, born at Basel, 1707, who is credited by Willis with being the first to suggest it. Willis devised the Willis odontograph for laying out involute teeth.

Selection of Pressure Angle: A pressure angle of 14½ degrees was selected for three different reasons. First, because the sine of 14½ degrees is nearly ¼, making it convenient in calculation; second, because this angle coincided closely with the pressure angle resulting from the usual construction at that time of epicy-

cloidal gear teeth; third, because the sides of all worm threads formerly used inclined 14½ degrees, so that the straight-sided involute rack has the same angle as the 29-degree worm thread.

The Formed Cutter: The invention of the formed cutter by Joseph R. Brown in 1864 made possible the use of accurately cut gearing and proved to be an important element in the introduction of the interchangeable system of involute gears.

Gear-Tooth Caliper. A vernier gear tooth caliper is used to measure the *chordal* thickness of a gear tooth. This chordal thickness, which is slightly less than one-half the circular pitch, may be determined as follows: First divide 90 degrees by the number of teeth in the gear, and then find the sine of the angle thus obtained. Next, multiply this sine by the pitch diameter; the product equals the chordal thickness. Before measuring the chordal thickness, it is necessary to set the vertical scale of the vernier gear tooth caliper so that the caliper jaws come into contact with the sides of the tooth at the pitch circle. To determine this vertical adjustment or "corrected addendum," the cosine of the angle equal to 90 degrees divided by the number of teeth, is first subtracted from 1; this difference is then multiplied by the pitch radius of the gear and the product is added to the addendum of the tooth. This final result equals the corrected addendum or the dimension to which the vertical scale of the gear tooth caliper should be set.

Gear-Tooth Chamfering. The teeth of gears in speed-changing mechanisms of the sliding-gear type, may be chamfered or beveled at the ends to facilitate sliding the gears into mesh when changing speeds. The pointed ends of the chamfered teeth engage more readily with the spaces of a mating gear.

Gear-Tooth Crowning. The crowning operation as applied to gear teeth is for the purpose of making the chordal thickness at the center slightly greater than at the ends. In other words, a crowned tooth is slightly barrel-shaped to avoid objectionable end or edge contact such as might be caused by misalignment or errors in gear manufacture. The crowning prevents excessive loading at the ends and is intended to increase the actual strength and wear resistance. The chordal thickness of the tooth at the center or at some specified intermediate point, usually is about 0.001 inch greater than the end thickness. Crowning is done in conjunction with gear-tooth shaving or finishing. A machine developed for this crowning and shaving operation is equipped with a controlling cam which is adjusted to vary the amount of crown and may be arranged to generate teeth of the conventional form or without crown. The crowning process is sometimes called *curve shaving.*

Gear-Tooth Curves. In developing or laying out the teeth or spur gearing, the idea is to form the teeth in such a way that the action of the gears will be like plain disks rolling together, the motion being transmitted smoothly and at a uniform rate. Similarly, bevel gearing is intended to reproduce the action of two frustums of cones rolling in contact with each other. There are various curves which might be applied to gear teeth in order to secure rotation between two gears having intermeshing teeth, but the *involute curve* is used almost universally because it has certain practical advantages which account for the fact that it has largely replaced the cycloidal curves formerly employed. See Involute Gear Teeth, Cycloidal Gear Teeth, and Gear-tooth Standards.

Gear-Tooth Grinding. Several types of machines for grinding gear teeth have been developed. These machines are used extensively for finishing hardened aircraft gears.

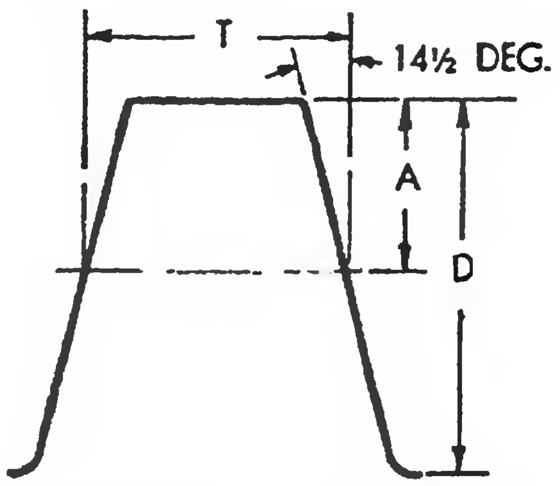
Single Wheel Method: One method of generating tooth curves by grinding is to use the flat face of a wheel which is perpendicular to the wheel axis and inclined from the vertical an amount equal to the pressure angle of the gear to be ground. In order to generate involute tooth curves, provision must be made for rolling the gear past the revolving grinding wheel, just as though an accurate gear were rolling along an accurate rack having the side of one tooth in the same position as the grinding face of the wheel.

Use of Two Grinding Wheels: A method of grinding two tooth surfaces at the same time consists in using two wheels which operate in different tooth spaces. The flat side of each wheel corresponds in location to the side of an imaginary rack tooth, and the generating action is the same as though the pitch circle of the gear were rolling along the pitch line of the rack, the motion being the same as with a single wheel. A master gear and rack mechanism is utilized to control the generating movement and to bring the gear into contact with the two grinding wheels.

Form-wheel Method: The formed-wheel method is based on the use of a grinding wheel having surfaces that are shaped to conform to the space between correctly formed gear teeth. This method is similar in principle to the use of formed cutters for cutting gear teeth, in that the shape of the grinding wheel is reproduced in the teeth.

Allowance: Just how must stock must be removed in grinding gear teeth to compensate for the greatest distortion that is likely to occur varies for different gears and frequently is affected by the method of heat-treatment. As a general rule, the removal of 0.003 to 0.005 inch from each tooth face is sufficient to correct all distortion, and in some cases, the removal of only 0.002 inch is sufficient. These allowances are based on the assumption that the

14½-Degree Full-depth Involute System

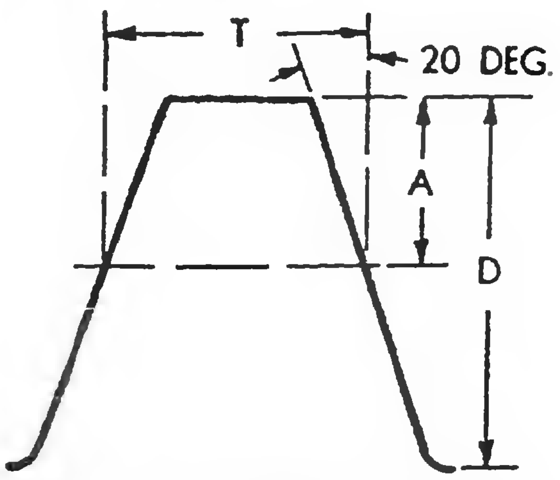


ADDENDUM A =
1 ÷ Diametral pitch
0.3183 × Circular pitch

TOTAL DEPTH D =
2.157 ÷ Diametral pitch
0.6866 × Circular pitch

BASIC THICKNESS T =
1.5708 ÷ Diametral pitch
0.5 × Circular pitch

20-Degree Full-depth Involute System

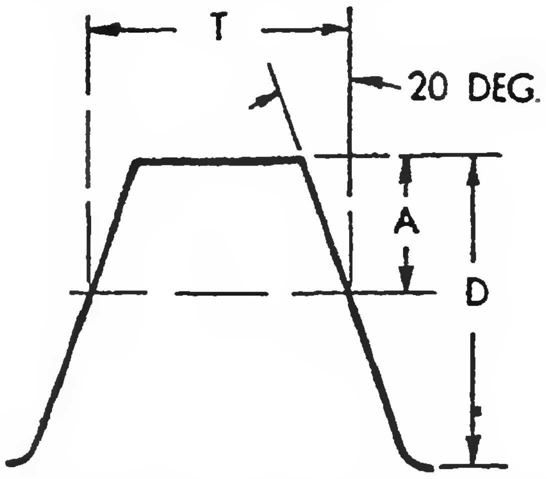


ADDENDUM A =
1 ÷ Diametral pitch
0.3183 × Circular pitch

TOTAL DEPTH D =
2.157 ÷ Diametral pitch
0.6866 × Circular pitch

BASIC THICKNESS T =
1.5708 ÷ Diametral pitch
0.5 × Circular pitch

20-Degree Stub Involute System

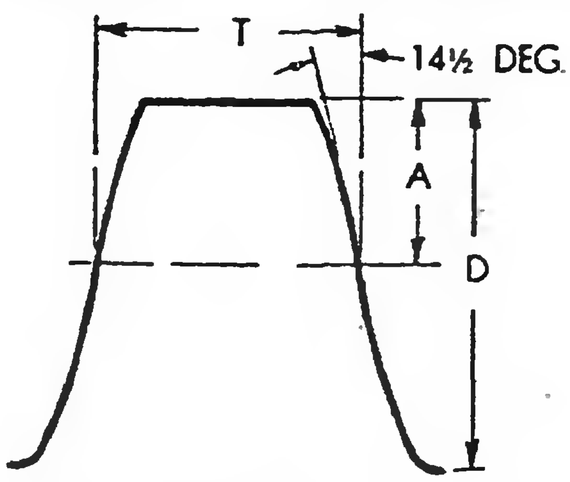


ADDENDUM A =
0.8 ÷ Diametral pitch
0.2546 × Circular pitch

TOTAL DEPTH D =
1.8 ÷ Diametral pitch
0.5729 × Circular pitch

BASIC THICKNESS T =
1.5708 ÷ Diametral pitch
0.5 × Circular pitch

14½-Degree Full-depth Composite System



ADDENDUM A =
1 ÷ Diametral pitch
0.3183 × Circular pitch

TOTAL DEPTH D =
2.157 ÷ Diametral pitch
0.6866 × Circular pitch

BASIC THICKNESS T =
1.5708 ÷ Diametral pitch
0.5 × Circular pitch

American Standard Basic Rack Tooth Forms

machine and cutters used for the preliminary cutting operation are of an approved type and in reasonably good condition.

Gear-Tooth Standards, American. There are four American standard spur-gear tooth forms, and these basic tooth standards are also applied to some extent in designing certain other types of gears. In establishing a gear-tooth standard, it is only necessary to give the proportions of the rack teeth because the rack is the basis or foundation of a standard system of interchangeable spur gears.

14 1/2-Degree Full-Depth Tooth: Standard tooth forms differ in regard to tooth depth for a given pitch and the angle or form of the basic rack tooth. The upper diagram (see accompanying chart) shows that the rack of a standard 14½-degree full-depth involute tooth. The total depth equals 2.157 divided by the diametral pitch and the other proportions are indicated by the formulas. This total depth is termed "full depth." The "stub tooth," referred to later, is somewhat shorter for a given pitch. This 14½-degree full-depth standard tooth form is very satisfactory, assuming that the tooth numbers are large enough to avoid excessive undercutting of the teeth. Undercutting will begin when the number of teeth is less than 32 and it may be excessive if the number is less than 22.

20-Degree Full-Depth Tooth: Practically the only difference between this 20-degree standard and the 14½-degree standard just referred to is in the pressure angle. (See second diagram.) The addendum, dedendum, and total depth are the same as for the 14½-degree full-depth tooth. This 20-degree rack tooth and gear teeth generated from it are wider at the base and consequently stronger than the 14½-degree standard as indicated by a comparison of the two basic rack diagrams. The larger pressure angle also reduces undercutting which begins when the number of teeth is less than 18 and may be excessive when the number is less than 14.

20-Degree Stub-Tooth Involute System: This standard differs from the 20-degree standard represented by the second diagram, in regard to the tooth depth, which equals 1.8 divided by the diametral pitch. The 20-degree pressure angle, in combination with a shorter tooth, strengthens the stub form and pinions with 12 and 13 teeth are only slightly under-cut. The length of contact between mating gears, however, is shortened, which tends to offset the increase in individual tooth strength and also tends toward greater noise when the gears are running, unless this tendency is offset by greater accuracy in cutting and mounting. Whether this noise tendency constitutes an objectionable feature may, for a given grade of gearing, depend upon the class of service. For example, noise which might be excessive in an automotive trans-

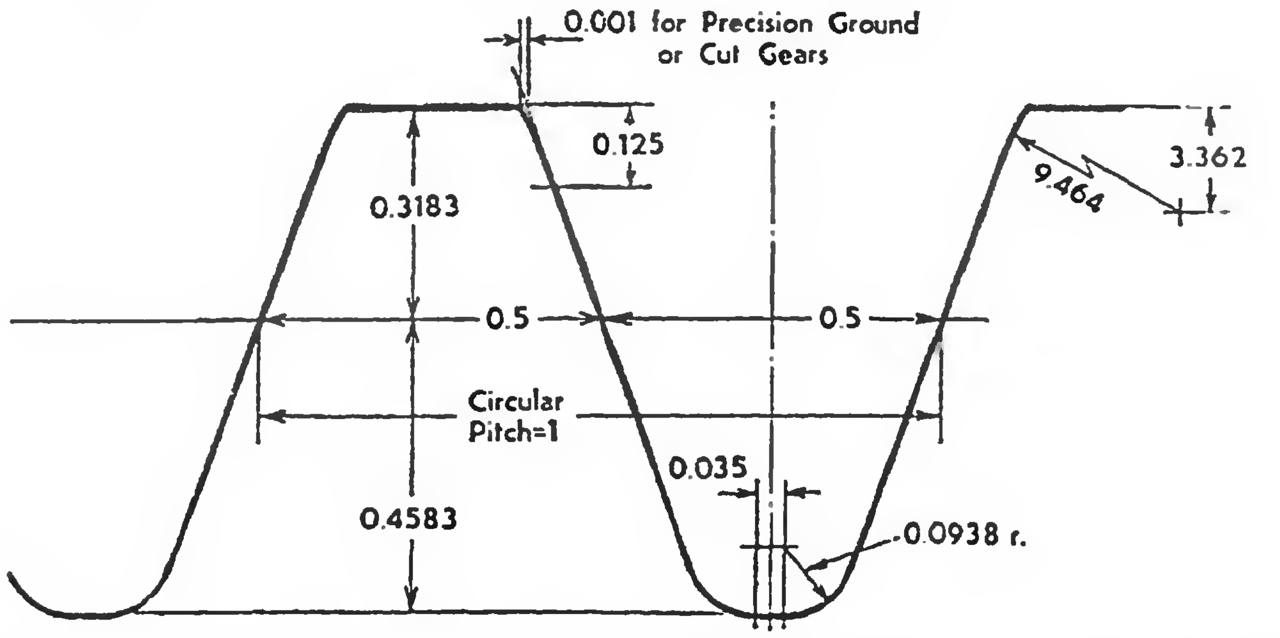
mission, would not be a factor in gearing applied to some other classes of machinery.

The 20-degree stub tooth is extensively used for automotive transmissions because relatively small gears are required and the maximum power-transmitting capacity for a given pitch or material is essential. For this class of service, however, very accurate gears are necessary and the mountings are designed to minimize noise. Helical forms of teeth are also utilized because they are conducive to smooth continuous action. The American Standard 20-degree stub tooth system is recommended by the American Gear Manufacturers' Association. Gears having this stub tooth may be used interchangeably with other stub-tooth systems and only the amount of clearance will be affected as the result of variations in tooth heights. See also Stub-Tooth Gears.

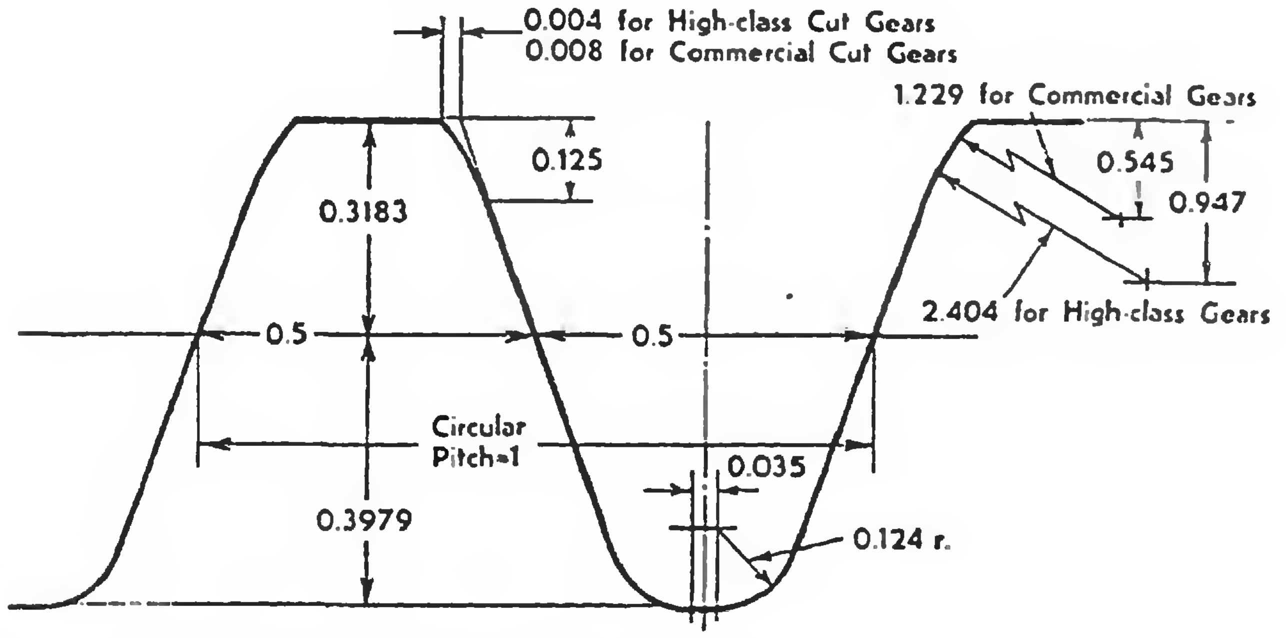
14½-Degree Composite System: This standard differs from the 14½-degree full-depth involute system in regard to the form of the basic rack teeth. The nominal pressure angle is the same and also the various formulas for determining tooth depth, addendum, dedendum, etc. The straight-sided or involute form of rack, however, is modified by introducing a cycloidal curve below the pitch line, and also one above it to make the tooth symmetrical as required for interchangeable gearing. Since it would be impracticable to produce in the shop a rack with cycloidal curves, or a cutter of this exact form, an approximate form of rack is used and meets practical requirements. The curves of this approximate rack are arcs having a radius equal to 3.750 divided by the diametral pitch. These curves are close approximations of the cycloidal curves on the theoretical rack. The 14½-degree composite tooth form was developed originally for use with the form milling process and gear teeth conforming to this standard generally are cut by form milling. They can, however, be produced readily on hobbing or other generating machines by making a hob or cutter of the basic rack form. If a hob is used, the relieving tool can be made to the form of the basic rack tooth. The line of tooth action is longer with the composite system than with the pure involute tooth form.

Gear-Tooth Standards, British. The British standard tooth form for spur gears is a 20-degree full-depth involute form. This same standard applies to single and double helical gears for connecting parallel shafts. For helical gears the tooth shape and proportions apply to a section at right angles to the helix, normal pitch being substituted for circular pitch. The standard specification includes the following classes:

Class A: Precision ground or cut gears suitable for peripheral speeds exceeding 2000 feet per minute.



Basic Rack Tooth Shape for Precision Ground or Cut Gears—20-degree Pressure Angle



Basic Rack Tooth Shape for High-Class or Commercial Cut Gears—20-degree Pressure Angle

Class B: High-class cut gears suitable for peripheral speeds between 750 and 3000 feet per minute.

Class C: Commercial cut gears suitable for peripheral speeds below 1200 feet per minute.

The range of speeds specified for the three classes permits considerable overlap. If the speed of any particular gear falls in either of two classes, it is implied that the lower class is suitable but the higher class may be selected to meet exceptionally severe conditions or to obtain a higher grade of work. This specification does not include traction gears, turbine or aviation gearing, or special applications.

Rack Tooth Shape: Basic rack tooth shape for unit circular pitch is shown by the accompanying illustrations. The upper drawing shows the basic rack for precision ground or cut gears (Class A) and the lower one, the basic rack for high-class and

commercial cut gears (Classes B and C). The pressure angle in each case is 20 degrees and the rack tooth has straight sides or the involute form except that a slight easing of the point is permissible. The amount of this easing or "tip relief" shall not exceed the following values as measured on the basic rack:

Class A: Precision ground or cut gears: 0.001 × circular pitch extending 0.125 × circular pitch in depth.

Class B: High-class cut gears: 0.004 × circular pitch extending 0.125 × circular pitch in depth.

Class C: Commercial cut gears: 0.008 × circular pitch extending 0.125 × circular pitch in depth.

The basic rack for Class A gears has the same addendum as the rack for Classes B and C, but the dedendum is greater. The shape of the space at the root of these basic rack teeth is approximately semi-circular. This bottom clearance space is a continuous curve and as nearly semi-circular in form as the tooth shape and system of cutting will permit. Although the increased depth of space due to the semi-circular clearance reduces the static strength, tests have shown that this form greatly increases the resistance to fatigue of hardened and heat-treated gears, and it is not considered detrimental to other types of gears made from iron, steel or bronze.

Pressure Angle: In establishing a single standard for general application to new work, the 20-degree full-depth tooth was recommended, although the committee fully realized that stub-tooth gearing and gearing with a pressure angle of 14½ degrees have been used successfully for many years and will, for certain purposes, continue to be used. This standard 20-degree pressure angle tooth possesses the desirable qualities of strength and ability to withstand wear, and, at the same time, is equal to other forms as regards quietness of running. Compared with the 14½-degree pressure angle, the strength at the root is considerably greater and undercutting in gears having small numbers of teeth is not so pronounced. The 20-degree full-depth tooth is approximately equal in strength to the 20-degree stub tooth, but has an advantage over the latter as regards wearing properties in having a longer arc of contact. Although the arc of contact is a little shorter as compared with the 14½-degree pressure angle, the relative radius of curvature of the tooth faces is greater, which more than compensates for the reduction in the length of the arc of contact.

Genelite. The material called "Genelite," is a bearing bronze made synthetically. The admixture of finely divided graphite with the bronze is done in such a manner that it results in a uniform distribution throughout the mass in a volume proportion as high as 40 per cent. This uniform distribution is accomplished by

mixing graphite with the powdered oxides (copper, lead, and tin oxides) composing the bronze, in a sufficient quantity to reduce the oxides and leave the desired amount of graphite after the reduction is complete. The mixture is then put through a reduction process, being kept in the powdered form known as "Genelite powder," until the final steps. These consist of pressing the partially reduced powder in heavy steel molds under a high pressure as nearly as possible to the desired size and shape, and then giving it a final heat-treatment. Besides its use for bearings Genelite is also used for facing the rotating parts of valves used in systems handling caustic solutions. Among the properties claimed for this material are those of not sizing or sticking and of being somewhat self-lubricating. The material has the appearance of bronze and can be easily ground, but is not easily machined. It was developed in the research laboratory of the General Electric Co.

General-Purpose Motor. According to the National Electrical Manufacturers Association adopted standard, a *general-purpose motor* (except synchronous motor) is any motor of 200 horsepower or less and speeds higher than 450 revolutions per minute, having a continuous time rating, and designed, listed, or offered in standard ratings for use without restriction to a particular application.

A *general-purpose synchronous motor* is any motor rated 200 horsepower or less at 1.0 power factor or 150 horsepower or less at 0.8 power factor and speeds higher than 450 revolutions per minute, having a continuous time rating, and designed, listed, or offered in standard ratings for use without restriction to a particular application.

Generating Gear Teeth. See Gear Cutting by Generating Process.

Generator, Alternating-Current. An alternating-current generator, or alternator or synchronous generator, as it is also termed, is a machine that transforms mechanical power into electrical power. It has a magnetic field and an armature for delivering alternating currents in synchronism with the motion of the machine; that is, currents having a frequency strictly proportional to the speed of the machine. The instantaneous values of the electromotive forces (commonly written E.M.F.) and the currents are constantly changing from maximum positive to maximum negative, but the specified or effective value is equal to the square root of the average value of the square of the instantaneous values, which, for a true sine wave, is equal to the maximum value divided by $\sqrt{2}$. Almost all alternating-current generators of large capacity are of the revolving-field type, because the transmission of a current under high voltage through collector

rings and brushes, as required in the revolving-armature type, causes break-down troubles, as it is difficult to insulate the rings and brushes effectively. The stationary-armature winding, however, may be easily insulated, as it is not subjected to the mechanical stresses of the revolving-armature type and the crumbling from vibration imparted by a revolving member.

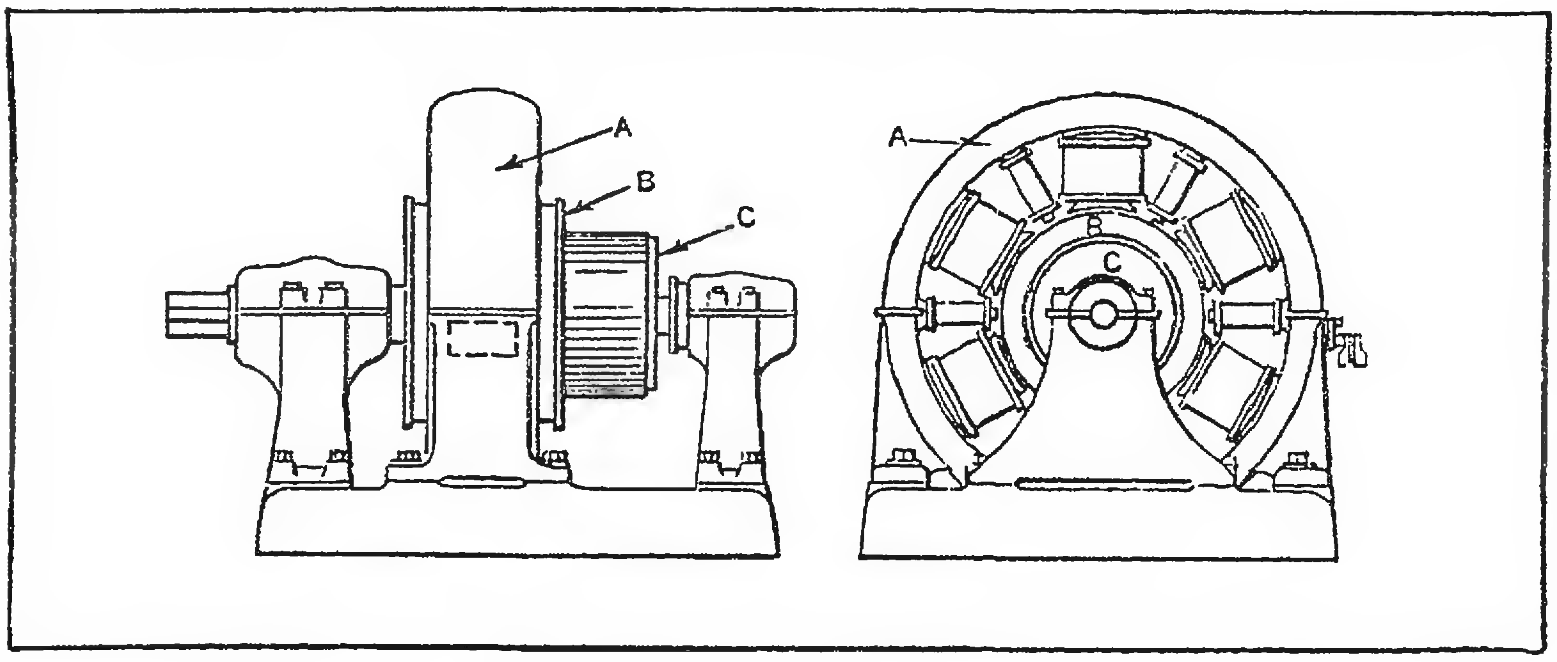
Alternating-current generators may be single-, two-, or three-phase machines, depending upon whether they generate a single alternating electromotive force, or two or more electromotive forces that differ in phase by a fixed amount; in the latter case they are also known as "polyphase generators." Three-phase generators are used almost exclusively on account of the saving that may be obtained. They are about two-thirds as heavy and as expensive as a single phase generator of the same rating. With the same line voltage and loss, the three-phase system will save about 25 per cent in the weight of the line conductors, as compared with either of the other systems—besides the reduced cost of line material and labor. Hence, when two-phase generators are required, it is usually for additions to an old system. The universal trade terms for alternating-current generators are: *ASB* for single-phase generators; *AQB* for two- or quarter-phase generators; and *ATB* for three-phase generators. In each case, *B* means revolving field.

Generator, Direct- and Alternating-Current. Both direct- and alternating-current electricity can be produced by a generator developed for use primarily with welding equipment. Because of the universal alternating or direct current feature, spot or tack, semi-arc and nickel-flash welding operations can be performed with alternating current, and if it is desired to perform other operations for which it is preferable to use direct current, this kind of current can be obtained immediately. The full capacity of the equipment can be obtained with both currents. As the same armature winding serves for both currents, no extra space is required for the winding as compared with that necessary in a generator delivering only one of the currents. The only extra parts required are two collector rings for the alternating current. The main feature of the generator is that either the alternating- or direct-current leads can be short-circuited right at the collector rings or the commutator without injury; the generator voltage simply dies down to a value that holds the current constant, and there is no injury of the generators while in this condition. With the release of the short circuit, the normal voltage is immediately obtained. The generator has a power take-off at both ends for driving equipment or machines.

Generator, Direct-Current. A direct-current generator is a machine that transforms mechanical power into electrical power,

giving a current that is unidirectional or non-pulsating. It is constructed on the principle that a conductor moved across a magnetic field, in a direction at right angles to the lines of force or magnetic flux, will induce an electromotive force in that conductor. Direct-current generators are used for light, power, and railway service; for all purposes there is a close similarity in the electrical and mechanical design, the main difference being in the use of larger commutators for the first two, due to the lower voltage and greater amount of current to be handled.

The direct-current generator consists essentially of two distinct elements, a stationary field *A*, and a rotating armature *B* (see illustration). The field is composed of electromagnets of alternate polarity arranged in a circle, as shown, while the armature consists of a system of conductors arranged on an iron drum and operating in the magnetic field set up by the electromagnets. As



Direct-current Generator

the conductors are acted upon alternately by north and south poles, the current generated in the conductors flows first in one direction and then in the opposite direction. To secure a constant flow of current in one direction, therefore, a device *C*, known as a *commutator,* is used to rectify the alternating, or pulsating, currents as they are generated in the armature conductors. This device, which constitutes a third essential element in a direct-current generator, consists of a number of copper segments or bars insulated from one another and connected to appropriate points of the armature winding. The potential, or voltage, of the bars will have a constantly varying value, which corresponds to the fluctuating potential induced in the conductors to which they are connected, as these conductors pass the pole pieces. The points of maximum potential on the commutator will, therefore, be equal to the number of field poles, as a conductor generates its maxi-

mum voltage while passing through the densest part of the pole flux; and although these maximum points are shifting rapidly from bar to bar around the commutator, their position relative to the stationary poles is fixed. This fact permits the collection of a constant-voltage direct current by means of contact brushes arranged to bear upon the commutator at equally-spaced points around its circumference.

Direct-current generators may be classified according to the manner in which they are "excited," that is, the manner in which the electromagnets are energized; they may be "separately excited," or "self-excited." When the generators are separately excited, the current for the field winding is taken from an outside source; when they are self-excited, it is drawn from the armature of the machine itself. Self-excitation is the form most commonly used on account of its simplicity, although the field current is then dependent upon the brush potential. When it is desirable to maintain a field strength independent of the brush potential, separate excitation should be used. Self-excited, direct-current generators may also be classified according to the manner in which the field windings are arranged; such as series-wound, shunt-wound, and compound-wound. See Series-wound Generator; Shunt-wound Generator; and Compound-wound Generator.

Generator, Double-Current. A double-current generator is a machine driven by mechanical power and producing direct current as well as alternating current from the same armature winding, which is connected to both commutator and collector rings. This type of machine is occasionally used for testing purposes.

Generator, Inductor Type. The inductor generator is a synchronous type in which both the field and armature windings are stationary and only the pole pieces revolve. Due to the varying reluctance of the magnetic circuit, caused by the revolving poles, the flux linked with the armature coils will vary periodically, and induce an alternating electromotive force in the armature winding. This type was extensively used before the introduction of the revolving-field alternator, which has proved to be far superior to the inductor alternator.

Generator Rating. According to the American Standard for Rotating Electrical Machinery, the rating of a generator shall consist of the output together with any other characteristics such as speed, voltage, frequency, and current, assigned to it by the manufacturer. The output for direct-current generators is usually given in watts or kilowatts (kw) available at the terminals at a specified speed and voltage, and for alternating-current generators in kilovolt-amperes (kva) available at the terminals at a specified speed, frequency, voltage, and power factor.

The various kinds of rating recognized are:

Continuous Rating: This rating defines the load which can be carried for an unrestricted period without causing any of the established standard limitations to be exceeded.

Short-Time Rating: This rating defines the load which can be carried for a specified time (5, 10, 15, 30, 60 or 120 minutes) without causing any of the established standard limitations to be exceeded.

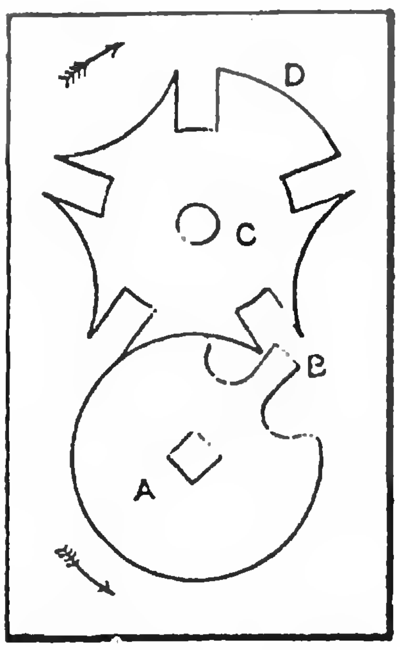
Nominal Rating: This rating defines the constant load which, having been carried without causing further measurable increase in temperature rise, may be increased 50 per cent in amperes at a specified voltage for two hours without causing any of the established standard limitations for nominally rated machines to be exceeded.

Continuous with Two-Hour 25 per Cent Overload Rating: This rating defines the load which can be carried continuously, immediately followed by a 25 per cent overload for two hours, without causing any of the established standard limitations to be exceeded.

The permissible temperature rise of the armature and field windings, the cores and mechanical parts adjacent to or in contact with the insulation, and the commutators and collector rings, above the temperature of the cooling medium (ambient temperature of the air in many cases) is also outlined in this American Standard.

Generator Winding. See Compound-wound Generator; Series-wound Generator; Shunt-wound Generator.

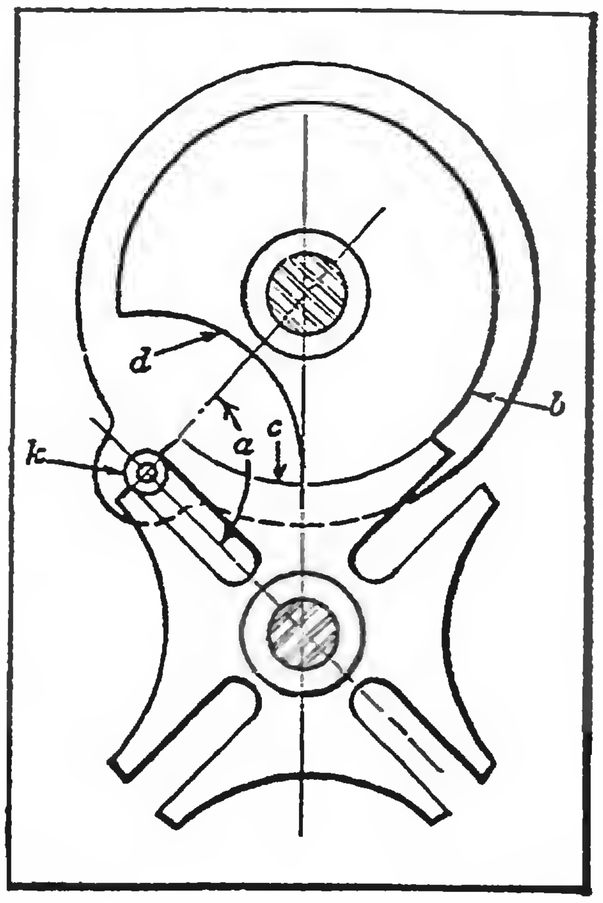
Geneva Stop. The Geneva stop is a simple form of mechanism applied to watches, etc., to prevent winding the main spring too tightly. The principle of the mechanism is illustrated by the diagram. A disk *A* has one projecting tooth *B*, and is fixed upon the spindle of the barrel or casing containing the main spring. Another disk *C* provided with notches that are engaged by tooth *B* is rotated through part of a revolution each time tooth *B* makes one complete turn and engages one of the notches or tooth spaces. As that part of disk *C* between the notches is curved to the same radius as disk *A*, disk *C* is locked and prevented from rotating during the time that the tooth *B* is out of engagement. When disk *A* is turned, the intermittent motion of disk *C* continues until the convex portion *D* comes around into engagement with disk *A*, thus preventing any further rotation. With this ar-



Geneva Stop

rangement, the number of revolutions for disk *A* can be positively regulated so that over-winding of the spring is avoided. When the winding action has ceased, the disks will return to their original positions as the mechanism of the watch is driven by the spring and runs down. The principle of the Geneva stop has been applied to various classes of machinery in order to obtain the intermittent motion resulting from this form of mechanism.

Geneva Wheel. The general type of intermittent gearing shown in the illustration is commonly known as a "Geneva wheel," because of the similarity to the well-known Geneva stop. Geneva wheels are frequently used on machine tools for indexing or rotating some part of the machine through a fractional part of a revolution. The driven wheel shown in the illustration has four radial slots located 90 degrees apart, and the driver carries a roller *k* which engages one of these slots each time it makes a revolution, thus turning the driven wheel one-quarter revolution. The concentric surface *b* engages the concave surface *c* between each pair of slots before the driving roller is disengaged from the driven wheel, which prevents the latter from rotating while the roller is moving around to engage the next successive slot. The circular boss *b* on the driver is cut away at *d* to provide a clearance space for the projecting arms of the driven wheel. In designing gearing of the general type illustrated, it is advisable to so proportion the driving and driven members that the angle *a* will be approximately 90 degrees. The radial slots in the driven part will then be tangent to the circular path of the driving roller at the time the roller enters and leaves the slot. When the gearing is designed in this way, the driven wheel is started gradually from a state of rest and the motion is also gradually checked.



Geneva Wheel

Geometrical Progression. A geometrical progression is a series in which each term is derived by multiplying the preceding term by a constant multiplier called the *ratio*. When the ratio is greater than 1, the progression is increasing; when smaller than 1, it is decreasing. Thus, 2, 6, 18, 54, etc., is an increasing geometrical progression with a ratio of 3, while 24, 12, 6, etc., is a decreasing progression with a ratio of ½.

Geometric Lathe. The machine known as a "geometric lathe" is a special machine designed for engraving intricate designs on fine dies or plates. The elaborate scroll work found on paper money is an example of the engraving done by the geometric lathe. While this machine is known as a "lathe," is is, in reality, a highly specialized type of engraving machine. The geometric lathe was invented by Charles W. Dickinson, and was first used for engraving bank-note plates in 1862. This machine produces an almost endless variety of geometric figures by utilizing various combinations of gears, cams, and eccentrics. By varying the patterns for treasury notes, postage stamps, revenue stamps, etc., counterfeiting is made difficult. Moreover, the operation of one of these machines requires an expert mathematician. The lathe has a number of superimposed flat plates which are actuated by cams and gearing, and the die to be engraved is held by the top platen or chuck. The hardened steel tool which is sometimes pointed with a diamond is fastened in a stationary position, and the die is given the various movements necessary to produce each pattern.

Georgia Corundum. This is a natural abrasive containing about 77 per cent of crystalline alumina, which constitutes the cutting material of the abrasive. It is mined in Georgia; hence the name.

Germanium. An element which is obtained as a by-product of the zinc industry. It is a gray-white crystalline material with a hardness of 6.25 Moh. Its atomic number is 32, has an atomic weight of 72.60, and a melting point of 958 degrees C. It has a valence of three and will form "chain" compounds like carbon and silicon. Crystals of germanium are used in the electronics field as rectifiers for changing alternating current to direct current, and in transistors for amplifying electric current at service temperatures not exceeding 85 degrees C. The salts of germanium are also used to increase the refractive properties of glass.

German Silver. German silver, also known as "nickel silver," is an alloy of copper, nickel, and zinc, the best quality consisting of 50 per cent of copper, 25 per cent of nickel, and 25 per cent of zinc. This quality, however, is the most difficult to work, but takes a fine polish and is frequently used for tableware to imitate silver. When the proportion of copper is somewhat higher, the alloy is suitable for rolling and for drawing into wire. German silver is known under probably a greater number of names than any other

alloy. In addition to the name "nickel-silver," it is also known as "Chinese white silver," or "packfong," "white copper," "silveroid," "Nevada silver," and "electrum." German silver can be hammered, rolled, stamped, and drawn. At the same time, it possesses the properties of being hard, tough, and not easily corroded, but, when exposed to the air, it tarnishes, becoming slightly yellow. At a heat above dull red, it becomes very brittle. German silver can be readily soldered. The usual composition of German silver solder is: Copper, 47 per cent; nickel, 11 per cent; and zinc, 42 per cent.

Gherkin's Latch. This is a mechanism used for automatically returning a machine member to the starting point or central position after it has been thrown out of this position by the action of the machine.

Gibs. A gib (also known as an adjusting or take-up strip) may be defined as a wedge or adjusting shoe the object of which is to insure a proper sliding fit between two machine parts, and to make possible the taking up of the wear after the proper adjustment has been lost through continued service. Briefly, therefore, the function of the gib may be said to be to prevent slackness between the slide and its slide-way, and to compensate for wear. Gibs are used extensively on various classes of machine tools. Gibs may be divided into three main groups, according to the mode of "setting-up" or adjusting. These groups include (1) gibs forced laterally by screws acting at right angles to the axis of the slide; (2) angular gibs pulled or forced sideways so as to have a wedge action between the slide and the slide-way; (3) gibs tapered longitudinally and thus having a wedge action.

Gibsiloy. Eight grades of nickel-silver, silver-nickel-tungsten, silver-nickel-molybdenum and silver-nickel-cadmium powdered-metal compositions which can be produced in button, wire, strip, or rod form. Can be headed into rivets or buttons for electrical contacts or coined to any shape required.

Gilbert. The gilbert is a unit of magnetomotive force, and is the amount of magnetomotive force that can be produced by a coil of $10 \div 4\pi$ ampere-turns, or 0.7958 ampere-turn. The magnetomotive force of a coil in gilberts equals 1.2566 times the ampere-turns. The abbreviation for magnetomotive force is mmf.

Ginsaw File. Ginsaw files are of knife shape and single-cut. This type has been supplanted, to a considerable extent, by the three-square ginsaw file, which is made either tapering or blunt of hand-saw slim steel, and is used for filing cotton ginsaws.

Giolitti Process. This is a method for carburizing work to be casehardened by packing the work with wood charcoal in a cylinder, heating the work to a carburizing temperature, and then injecting a current of carbon dioxide into the cylinder. With the use of this process, a more rapid penetration of the carbon at the surface of the work can be obtained than with an ordinary solid carburizing mixture.

Girder. A beam of wood or iron, which is supported at each end upon walls or piers, and which supports a superstructure or load, such as a floor, a wall, or the roadway of a bridge, is known as a *girder*. When a girder is composed of upper and lower horizontal members united by vertical and diagonal bars, the girder is known as a *lattice* girder. When built up from steel plates and angles into compound shapes, forming I-beams or T-beams, the girder is commonly known as a *plate* girder. If built up from plates and angle irons to form a rectangular cross-section, the girder is known as a *box* girder. All girders, however, in their mechanical sense are *beams*.

Gland. A bushing or sleeve which fits around a shaft or stem and is used to compress the packing in a stuffing box or valve to prevent leakage.

Glass Cutting. Sometimes it is necessary to cut plate glass so as to leave the edges smooth and straight. If this work is attempted with the aid of a diamond glass cutter and rule, the glass will break with a ragged edge. A method of overcoming this difficulty, which has been used in cutting plate glass as thick as ½ inch and with excellent results, is as follows: First obtain a good diamond glass cutter, and with this tool scratch the glass along the line on which it is to be cut, using any good straightedge to guide the diamond. In this connection it may be mentioned that the deeper the cut the more uniform the surfaces of the cut edge will be. After laying the glass on a cold surface with the cut side up, for which purpose the surface plate is very satisfactory, an iron or steel rod about ¼ inch in diameter is heated to a dull red. This rod is then laid along the line scratched by the diamond point and pressed lightly against the glass. When held in position for from one to four minutes—depending on the thickness of the glass—it will be found that the glass will crack along the line, leaving a uniform surface.

Glass Drilling. There are several methods of drilling holes in glass. For holes of medium and large size, use brass or copper tubing, having an outside diameter equal to the size of hole re-

quired. Revolve the tube at a peripheral speed of about 100 feet per minute, and use carborundum (80 to 100 grit) and light machine oil between the end of the pipe and the glass. Insert the abrasive under the drill with a thin piece of soft wood so as to avoid scratching the glass. The glass should be supported by a felt or rubber cushion, not much larger than the hole to be drilled. If practicable, it is well to drill about halfway through and then turn the glass over and drill down to meet the first cut. Any fin that may be left in the hole can be removed with a round second-cut file wet with turpentine. For comparatively small holes, a solid drill is often used. Use steel rod or an old three-cornered file, grinding the end to a long tapering triangular shaped point. Grip the drill in a chuck and rotate rapidly. Use a mixture of turpentine and camphor as a lubricant. Holes up to ½ inch in diameter can be drilled in glass with a flat drill which has been hardened in sulphurous acid, a mixture of turpentine and camphor being used as a lubricant. Ordinary twist drills are also used for drilling glass, the turpentine and camphor mixture being used as a lubricant. The glass is drilled about halfway through and then turned over so that the remaining depth may be drilled from the opposite side.

Glass Fiber. See Fiber Glass.

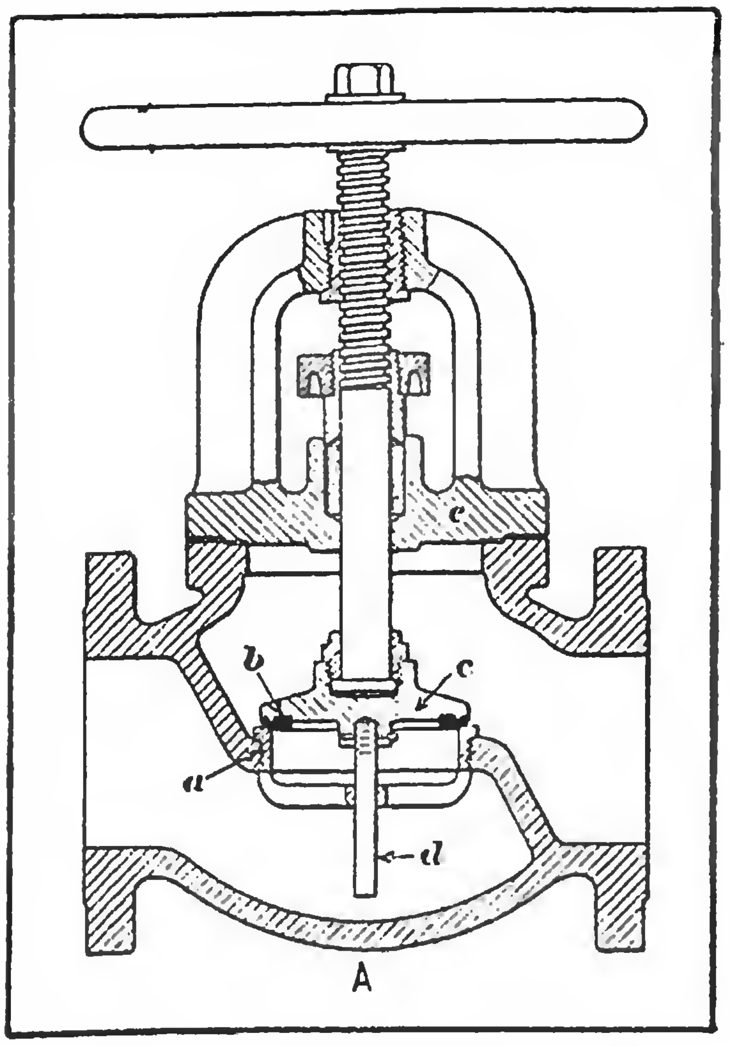
Glass Graduating. See Graduating on Glass.

Glazed Grinding Wheel. A wheel is "glazed" when the cutting particles have become dull or worn down even with the bond, which latter is so hard that the abrasive grains are not dislodged when too dull to cut effectively. Glazing may indicate either that the wheel is too hard for the work, or that the wheel speed is too high. The remedy, then, for glazing is to decrease the speed or use a softer wheel.

Glazing. The roughing operation, preparatory to finishing knife blades and cutlery, is performed with solid grinding wheels and the polishing is known as fine or blue glazing, but these terms are never used when referring to the polishing of hardware parts.

Gleason System of Bevel Gears. See Bevel Gears, Gleason System.

Globe Valves. One of the heavier types of globe valves is shown by the sectional view. This type of valve has a metal seat formed by the screw bushing *a*, against which the ring *b*, which



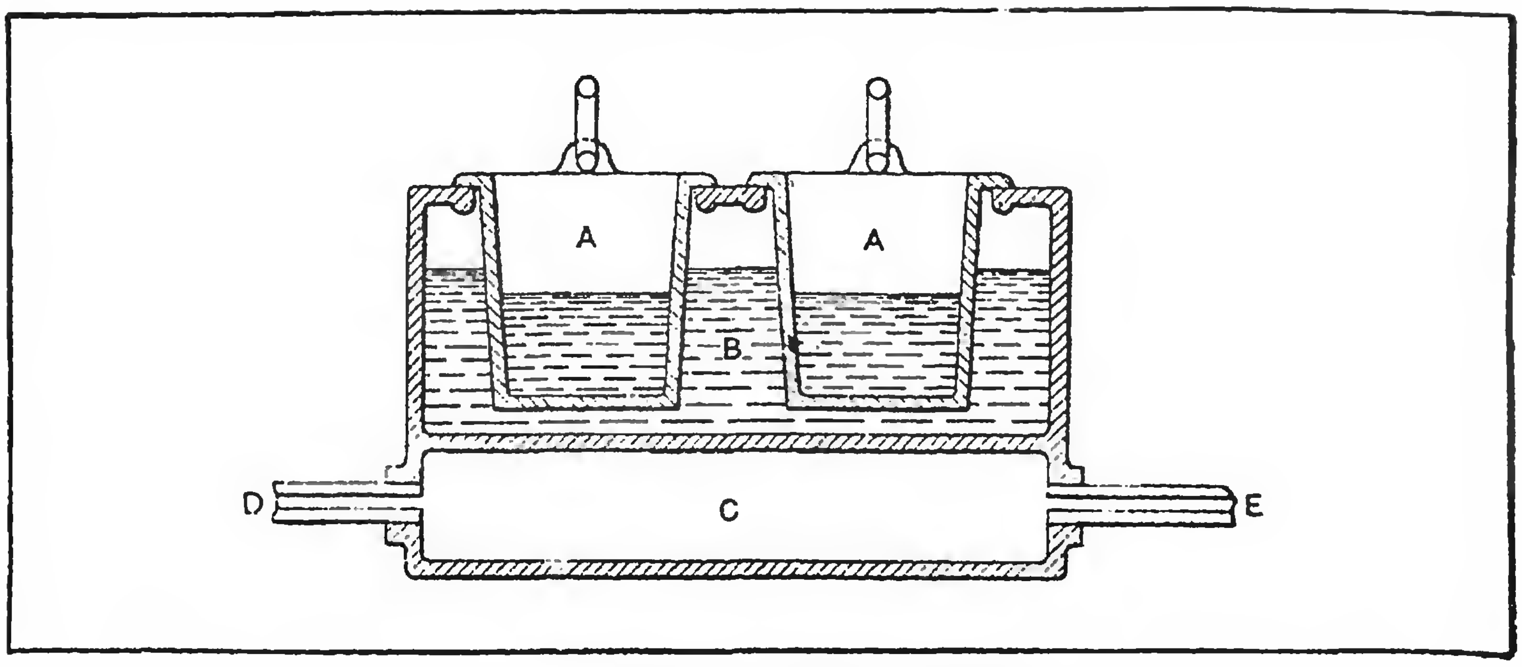
Globe Valve

forms a portion of the disk *c*, is forced by the raising or lowering of the stem to which the handwheel is attached. In this particular valve, the bronze bushing is provided with a guide through which a pilot *d* on the end of the valve-stem passes in order to assist keeping the moving parts in their correct positions. The stem of the valve passes through the bonnet *e* and is made tight by packing it with suitable material. In smaller valves of the globe type, a metal seat is not always employed, a ring of fiber or vulcanized rubber composition being used instead. A fiber ring of this kind can be easily replaced, so that the valve can be kept tight without trouble. The smaller valves are also made with metal seats so constructed that they can be readily re-ground to make the seat perfectly tight. Valves which have this provision are generally termed *re-grinding valves*. The screw on the valve-stem is generally of coarse pitch, and is sometimes a multiple screw, so as to permit opening the valve quickly. Valves of this kind are frequently made in angle form in order to take the place of elbows in the piping. There is a difference of opinion regarding which should be the pressure side of the valve. Many prefer to so connect the valves that the pressure is against the under side of the disk, as with this arrangement the stem of the valve can be readily packed when the valve is closed. When the pressure is on the top side of the disk, however, there is an advantage in that the thrust is against the valve-seat and not against the threads of the valve-stem.

Globoid Gearing. See Hindley Worm-gearing.

Glucinum. Glucinum is an alternative name used for the chemical element *beryllium;* the symbol is Gl, or sometimes G. The name "beryllium" has been used for many years, but recently the original name "glucinum" has been adopted by chemists, and both names are used to some extent, at the present time. For the properties of the element, see Beryllium.

Glue Heaters. Glue is always heated or boiled in a double boiler to prevent overheating and burning. The glue is placed in



Steam Glue Heater

a pot that fits into a vessel containing water. The water in the outer vessel is heated either by an open flame, an electric current, or by steam. A sectional view of a simple steam glue heater is shown. The receptacles *A* are for holding the glue; *B* is the water container, and *C* is the steam jacket. The live steam enters at *D*, passes through the jacket and out at *E*. The flow of steam is controlled by a globe valve at the inlet.

Glues for Wood. The glues that are adapted for gluing wood according to a report of the Forest Products Laboratory, U. S. Forest Service, Madison, Wis., may be conveniently divided into five classes as follows:

1. Animal glues, which are made from the hides, hoofs, horns, bones, and fleshings of animals, mostly cattle. These glues come in dry form, and must be mixed with water and melted.

2. Casein glues, which are made from casein, lime, and certain other chemical ingredients. They are commonly sold in prepared form, requiring only the addition of water, but may be mixed by the addition of the separate materials to the water.

3. Vegetable glues, which are made from starch, usually cassava starch, and sold in powdered form. They may be mixed cold with water and alkali, but heat is commonly used in their preparation.

4. Blood-albumin glues, which are made from soluble blood albumin, a product recovered from the blood of animals. These glues must be mixed just before use, since they deteriorate rapidly on standing.

5. Liquid glues, which are commonly made from the heads, skins, bones, and swimming bladders of fish. Some liquid glues are made from animal glue and from other materials. They come in prepared form ready for immediate use.

Animal Glue: Animal glue, frequently referred to as "hot

glue," is familiar to all woodworkers. The principal desirable properties of animal glue are its great strength and reliability in the higher grades, its free-flowing consistency, and the fact that it does not stain wood. So far no glue has been found to be as suitable as animal glue for handspreading on irregular shaped joints. The price of animal glue is the chief factor that limits its use. The fact that it is not highly water-resistant is occasionally a drawback.

Casein Glue: Casein glue has sufficient strength for either veneer or joint work. It is used cold, and when properly mixed it can be spread with a brush. The property most featured is its high water-resistance, which makes it suitable for gluing articles to be used under moist conditions. Not all casein glues are water-resistant, however; there are some on the market which are made to compete with vegetable glue, and for which no great water-resistance is claimed. Among the disadvantages of casein glues are their tendency to stain thin veneer and the relatively short working life of some kinds. It is claimed that this trouble has been overcome to a certain extent in some glues. They are somewhat harder on tools than animal and vegetable glues.

Vegetable Glue: Vegetable glues have found wide use because they are cheap, can be used cold, and remain in good working condition free from decomposition for many days. They are extremely viscous, and it is not practicable to spread them by hand. Their lack of water-resistance and the fact that they usually cause staining in thin fancy veneer are factors limiting their use. They set relatively slowly, and for this reason are not so well adapted for joint work.

Blood-albumin Glue: Blood-albumin glue has shown notably high resistance to moisture, especially in the boiling test. This makes it particularly suitable for gluing plywood which is later to be softened in hot water and molded. The production of molded plywood articles has been very limited, but it offers a good field for future development. In the past the chief drawback to the use of blood glues has been the necessity for hot-pressing, but tests have shown that a highly water-resistant blood glue may be developed which can be cold-pressed successfully.

Liquid Glue: Liquid glues are, in general, similar in properties to animal glue. Some brands are quite equal in strength to good joint glues, but other brands are very weak and unreliable. Their great advantage is that they come in prepared form, ready for immediate use. This makes them particularly suitable for patch work and small gluing jobs. The factors that limit their use are their high price, their lack of water-resistance, and the difficulty in distinguishing between good and poor brands.

Veneer and Joint Glues: Generally speaking, present vegetable

and blood-albumin glues are veneer glues, while animal and casein glues are used both as veneer and as joint glues. As between animal and casein glue for joint work, if freedom from staining is important, animal glue is preferable; if water-resistance is of importance, then a casein glue should be selected. Because of the necessity of heat in the preparation and use of animal glue, the casein cold glue will probably be favored if both glues are otherwise equally well adapted.

Glues Used in Polishing. There are three kinds of glue, namely, bone, hide stock, and fish glue. Hide stock glue is most generally used in the polishing industry. It is made from the skins of cattle, rabbits, and other animals. Glues are often blended; for example, a sheep stock and goat stock glue make an exceptionally strong holding medium, and, when mixed with ox fleshings, form a glue which has more strength than a glue made entirely from rabbit or some other similar stock. The cheaper grades of glue are usually mixtures of bone and hide glues.

Gluing Practice. The following information on gluing practice is based upon a report of the Forest Products Laboratory, United States Forest Service, Madison, Wis.

Weakness in glued joints may be caused (1) by allowing the glue to become too cold before applying pressure; (2) by using glue that is too thin and is squeezed out of the joint; or (3) by allowing the glue to dry too much before applying pressure. These three mistakes are the most common ones in gluing practice, and they are known as the "chilled joint," the "starved joint," and the "dried joint," respectively.

Strong joints may be obtained by changing either pressure, assembly time, or temperature, these being the three most important factors in the gluing operation when animal glue is used. Thus a good joint can be made from chilled glue by increasing the pressure, or the glue may be kept from becoming chilled and a good joint obtained if either the assembly time is decreased or the room temperature increased. If the glue is thin, starved joints may be avoided by decreasing the pressure, although such practice is not always recommended. Better average results are obtained if the consistency of a thin glue is increased either by increasing the assembly time or by decreasing the room temperature.

No amount of pressure will produce a good joint from dried glue, but by decreasing either the assembly time or the temperature to which the wood is subjected, a good joint can be made before the glue has dried out. Assembly time, room temperature, and wood temperature are chief among the factors affecting the consistency of an animal glue at the moment pressure is applied.

Pressure then must be adjusted to suit the consistency of the glue, the thicker mixture requiring the greater pressure.

Glycerine Anti-Freezing Mixtures. Glycerine raises the boiling point of water and does not evaporate like alcohol, but it is said to be somewhat more injurious to any rubber connections used between the radiator and engine. The freezing temperatures of distilled glycerine and water mixtures are as follows: 20 per cent glycerine (by volume) added to cooling water—freezing temperature, + 21 degrees F.; 30 per cent, + 12 degrees F.; 40 per cent, zero; 50 per cent, — 15 degrees F. below zero.

Glycerine in Hydraulic Machinery. Glycerine has been used extensively in hydraulic presses and similar machinery because it acts to a certain extent as a lubricant, preserves the flexibility of cup leathers, has a high viscosity which makes it less likely to leak through fine pores in castings and defects in joints, and, finally, freezes at a very low temperature. It is also found that in many instances glycerine acts as a protection against corrosion of metallic surfaces. There are, however, other instances where apparently it either induces or accelerates corrosion. From an extensive investigation it would appear that whenever two metals of different electrical potential are employed in hydraulic apparatus with glycerine as the working fluid, the metal that constitutes the negative pole of the electric couple is always the one attacked. The conclusion is that in hydraulic or hydro-pneumatic apparatus employing glycerine as a working fluid, the parts should be so selected that contact of two different metals in the presence of the glycerine is always avoided.

Gold. Gold is the most malleable of all metals and is also extremely ductile. It may be beaten into leaves thin enough to transmit a greenish light, and one grain of gold has been drawn into wire 500 feet in length. One of the most remarkable properties of gold is that it is permanent in both moist and dry air at all temperatures, and that it is insoluble in all acids except in aqua regia (a mixture of hydrochloric and nitric acids) which will dissolve it. Chlorine and solutions that generate chlorine will dissolve gold. Pure gold is rarely used in the arts or industries, because of its softness, it being nearly as soft as lead and much softer than pure silver; it is, therefore, generally alloyed with either copper or silver. Gold coins and gold ornaments are always made of alloys of gold and copper, or gold, copper, and silver. The coins of the United States are composed of 9 parts of gold and 1 part of copper. The specific gravity of gold, when cast, varies from 18.3 to 19.35, but the specific gravity of pure gold obtained by precipitation may be anywhere from 19.55 to 20.7. Generally,

the specific gravity of commercial gold is given as 19.3. The melting point of gold is 1063 degrees C. (1945 degrees F.). As a conductor of electricity, gold ranks next to silver and copper. Its electrical conductivity is equal to 76.7 (silver = 100).

Gold Amalgam. Alloys formed by mercury and other metals are known as *amalgams.* Gold amalgam is an alloy of gold and mercury. It is used in gilding.

Gold, Mannheim. See Mannheim Gold.

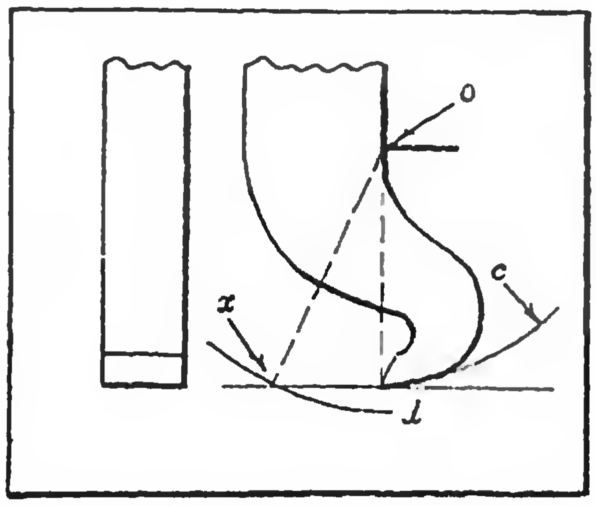
Gold-Plating. Gold is universally plated from a solution of potassium gold cyanide, $KAuC_2N_2$, held in solution by potassium cyanide. The appearance of the deposited gold depends upon the temperature of the bath. A hot bath gives deposits of greater density and uniformity, and richer tones. Any other metal than copper must be copper-plated before gilding. The following bath is suitable for cold gilding: 54 grains of gold in the form of fulminating gold, from 0.35 to 0.5 ounce of 98-per-cent potassium cyanide, and 1 quart of water. Fulminating gold is prepared by adding ammonia to a solution of gold chloride. The fulminating gold is precipitated, filtered, and washed, and then dissolved in potassium cyanide, while still moist; if dried, it is highly explosive. Too much potassium cyanide causes the gilding to be pale. The following bath is suitable for hot gilding: 15.4 grains of gold in the form of fulminating gold; 77 grains of 98-per-cent potassium cyanide; and 1 quart of water. The temperature is from 158 to 176 degrees F. The current density used in gold-plating is from 0.93 to 1.4 ampere per square foot, at from 1 to 3 volts; the anodes are of fine gold. When very large objects are to be gilded, anodes of corresponding dimensions are required in order to insure a uniform current density. As it would be too expensive to use large gold plates, carbon may be substituted.

When gold-plating the insides of silver-plated utensils, the gold solution is poured into the vessel, and a gold anode suspended in the center from the positive pole of the generator; the negative is attached to the article itself. Pewter vessels are first copper-plated before undergoing the gilding or silvering process. During the operation of plating, it improves the solidity of the deposition to scratch-brush frequently, which also prevents the work turning to a dead brown-black. Red gilding is produced by the addition to the bath of copper cyanide in small amounts until the proper color is obtained. Green gilding is produced by the addition of silver cyanide. See also Electroplating.

Goniometer. The goniometer is an instrument used for measuring the angles of crystals. There are two kinds of goniometers, the *contact* goniometer and the *reflecting* goniometer. The first

type is somewhat similar to the simplest type of draftsman's protractor, except that it is provided with an arm or rule pivoted at the center of the graduated semi-circle. The reflecting goniometer is an instrument of great precision, and is always used for accurate measurements of angles, when small crystals with bright faces are available. Several forms of this instrument have been devised, all being based upon the reflection of the light from the crystal faces.

Goose-Neck Tool. The peculiarly-shaped tool shown by the front and side views of the accompanying diagram, is especially adapted to finishing cast-iron surfaces. This type is known as the "goose-neck," because of its shape, and it is intended to eliminate chattering and the tendency which a regular finishing tool has of gouging into the work. By referring to the side view which represent this type of tool applied to a planer, it will be seen that the cutting edge is on a line with the back of the tool shank, so that any backward spring of the tool while taking a cut would cause the cutting edge to move along on arc c or away from the work. When the cutting edge is in advance at some point x, as with a regular tool, it will move along an arc a, if the strain of the cut causes any springing action, and the cutting edge will gouge in below the finished surface. Ordinarily, the tool and the parts of the planer which support it are rigid enough to prevent such a movement, so that the goose-neck tool is not generally used.



Goose-neck Planer Tool

Gordon's Formulas. These formulas were developed for the calculation of the strength of columns. They are also known as Rankine's formulas, which see.

Grade of Grinding Wheel. See Grinding Wheel Grade and Grain.

Graduating. The dividing of circular and straight scales into a given number of equal spaces or divisions is known as graduating. The type of machine or tool used for graduating and the method of producing the graduation marks or lines varies with different classes of work, depending upon the degree of accuracy necessary and the form of the parts to be graduated. The work of graduating may be divided into two branches, which include, first, the method of spacing, and second, the means for making suitable marks or lines upon the parts to be graduated.

The machines used in laboratories and by tool and instrument manufacturers, for graduating various kinds of straight scales,

may be classified as the *precision screw* type and the *pantograph* type. The former is equipped with a very accurate lead-screw, which, by means of a suitable indexing or spacing mechanism, is rotated an amount depending upon the spacing required, and as this screw actuates the work-holding table, a tool that is given a cross-movement makes graduation lines either in a "resist" or directly upon the work. The pantograph machines have a pantograph mechanism which serves to reproduce, on a smaller scale, the graduation lines or figures which have been previously cut in a pattern or master scale.

The marks or lines which represent divisions or spaces on graduated scales, etc., may be formed by the etching process, by the direct-cutting action of a tool, or, for some grades of work, by the stamping or impression process. With the etching process, the part to be graduated is first covered with some acid-resisting material or "resist," as it is called, and then the lines or figures are cut into this resist by a mechanically-guided graduating tool, thus exposing the metal wherever these lines or figures are made. An etching acid is then applied, and, wherever the metal is exposed, the acid eats into the surface and forms the division lines. When very fine graduation lines are needed the general practice is to employ the direct-cutting method, since the marks obtained by a very sharp-pointed tool are finer and more accurate than is possible to obtain by the etching process. See Etching "Resists" and Etching Acids.

Graduating on Glass. When graduation lines are etched on glass, a resist of paraffin or beeswax may be used. The lines and any other additional figures or designs required are then drawn into the resist the same as when operating on metal. Concentrated hydrofluoric acid is used for etching glass, and a little pigment is sometimes rubbed into the etched lines to make them more visible.

Grainal. These alloys are used to produce desirable properties in steel. One contains 25 per cent vanadium, 15 per cent titanium, and 10 per cent aluminum; another contains 13 per cent vanadium, 20 per cent titanium, and 12 per cent aluminum; while a third contains 20 per cent titanium, 20 per cent aluminum, and 6 per cent zirconium. They make possible the production of steel of uniform properties from heat to heat; the conversion of some water-hardening steels into oil-hardening; the production of steel of unusual physical properties at economical cost; and the addition of alloys to steel without complicating the usual steel making processes.

"Grain" of Grinding Wheel. See Grinding Wheel Grade and Grain.

Gram-Calorie. Gram-calorie is a thermal unit based on the metric system, designating the amount of heat required for raising the temperature of one gram of pure water one degree C. One gram-calorie = 0.003968 British thermal units; 1000 gram-calories = 1 kilogram-calorie.

Granite. Granite is one of the rocks or stones consisting principally of quartz and felspar, which is valuable as a building material, as a material for foundations, etc. The general properties of granite may be specified as follows: The weight of granite per cubic foot is 170 pounds; the specific gravity averages about 2.72; the compressive strength per square inch is about 15,000 pounds; the shearing strength per square inch is about 2000 pounds; the tensile strength per square inch is about 1500 pounds; the modulus of elasticity is about 7,000,000; and the coefficient of linear expansion due to heat, for each degree F., is 0.000004.

Graphalloy. Graphalloy is a trade name for a metallized graphite made by forcing molten metal into graphite of a porous nature by the application of air pressures up to 5000 pounds per square inch. Graphalloy is adapted for bearing bushings where the application of oil is either objectionable, difficult, or likely to be neglected, and also for brushes and contacts for electrical machinery.

Graphic Formula. In chemistry, a graphic formula is one which shows the valence of the atoms and the manner in which they are united in a compound.

Graphite. Graphite is a form of mineral which consists of the chemical element carbon. Graphite is very dark in color with a bright metallic luster, and is one of the softest of the minerals. Its specific gravity is about 2.2. Graphite occurs in nature mainly in crystalline rocks, and is also produced artificially on a large scale in the electric furnace. In the industries, graphite is used as a lubricant, as a material for crucibles, for foundry facings, and as a material for electrodes. It is also widely used in the manufacture of pencils, polishes, and paint. A special variety of graphite used for lubrication purposes is known as "deflocculated graphite." Deflocculated graphite, when suspended in water, is known by the trade name "aquadag." When suspended in oil, the trade name "oildag" is used. Graphite has valuable lubricating properties. See Deflocculated Graphite.

Graphite Crucible. This is a pot or container made from a mixture of Ceylon graphite, clay, and pure sand, used for the melting of metals. Graphite crucibles are more generally used than clay crucibles, because they can be recharged cold, will stand rough handling, and have a longer life.

Graphitic Carbon. This is carbon in the form of graphite. In cast iron it is merely mixed with the iron and is not in chemical combination with it. For the effect of graphitic carbon in cast iron, see Cast Iron.

Graphitic Steel. Graphitic steel contains approximately 1.50 per cent total carbon and around 1.00 per cent silicon, and in one form carries approximately 0.25 per cent molybdenum. It can readily be forged to shape from the "as rolled" condition, but before machining to shape it must always be normalized and annealed; this precipitates part of the total carbon in the form of free graphite, uniformly distributed throughout the steel, and develops the spheroidized pearlitic structure so well suited to good machining. Quenching develops a martensitic structure, the steel reacting in much the same manner as eutectoid tool steel. The resulting dies and punches show remarkable hardness and toughness, and are highly resistant to wear. For water-hardening uses, no molybdenum is added, this type of graphitic steel being known as "Graph-sil." When special toughness is required or freedom from distortion is essential, the oil-hardening "Graph-mo" is used.

Graphitizing. Graphitizing, according to the S.A.E. definition, is a method of annealing cast iron whereby some or all of the combined carbon is transformed into free or uncombined carbon.

Grate Area. The grate area is the area of the grate of a furnace, usually expressed in square feet. A simple rule for calculating the grate area of a boiler when the probable rates of combustion and evaporation are known is as follows: Multiply the horsepower of the boiler by 34.5 and divide the result by the product of the rate of combustion times the rate of evaporation; the quotient is the grate area in square feet.

Gravity. The attractive force that exists between the earth and all bodies at or near its surface is called "gravity." Weight is due to gravity. A body has weight because it is pulled downward by the force of gravity, and the amount that it weighs is a measure of this pull. A piece of iron, for example, weighs one pound when it is of such a size and density that it is drawn to the earth by a force equal to that which attracts a standard pound weight. The weight of a body (that is, the force by which it is attracted to the earth) varies slightly with the locality. Thus weight varies with altitude. A body weighs the most at the surface of the earth, as the attraction is there the strongest. Below the surface its weight decreases in the same ratio that its distance from the center of the earth decreases. Above the surface, the weight decreases in the same ratio that the square of the distance from the center increases. Weight also varies with the

latitude, or distance north and south of the equator. In passing from the equator to either pole, the attraction of gravity increases by 1/568 of its original amount. This is due to the fact that the earth is not a perfect sphere, the polar diameter being 26 miles shorter than the diameter at the equator. At the poles, however, a body would actually weigh more than this, or about 1/193 more than at the equator. The difference, 1/289, is due to the rotation of the earth on its axis, the effect of which is to produce a force directly opposite to that of gravity (centrifugal force), which is greatest at the equator and diminishes in moving from it, until at the poles it becomes zero.

Falling Bodies: Under the influence of gravity alone, all bodies fall to the earth with the same velocity and with the same acceleration. The fact that heavy bodies actually fall more rapidly than those of less weight or density, as would be observed in the dropping of a stone and a leaf, is due solely to the greater retarding effect of the air upon the latter. Weight does not affect the time of fall. Weight is the measure of the attractive force of gravity, and if one body weighs twice as much as another, the attraction of gravity upon it is two times as great as upon the lighter body; but as this force must accelerate twice as great a mass in the former body as in the latter, the velocity of each must be alike. An apparatus used to prove this consists of a long glass tube with closed ends, so arranged that the air can be exhausted. When this has been done, it is found that objects of varying sizes and weights will fall from one end of the tube to the other with equal rapidity. The value of the acceleration due to gravity is commonly denoted by the letter g. The acceleration increases with the latitude and decreases with the elevation above sea level. Its value at the level of the sea in the latitude of New York is 32.16 feet per second per second. (In the metric system g equals 9.81 meters per second per second at 45 degrees latitude and sea level.) As the velocity increases 32.16 feet per second every second, the velocity after T seconds will be:

$$V = gT,$$

where V = velocity in feet per second. The space in feet passed through by the falling body in T seconds equals the average velocity (which is ½ V) multiplied by the time:

$$S = \frac{1}{2} VT,$$

where S = space in feet which the falling body passes through in T seconds. These two formulas are the basis of all formulas relating to falling bodies.

Gravity Curve. An easy working cam curve is the one known as the "gravity curve." This curve has a constant acceleration

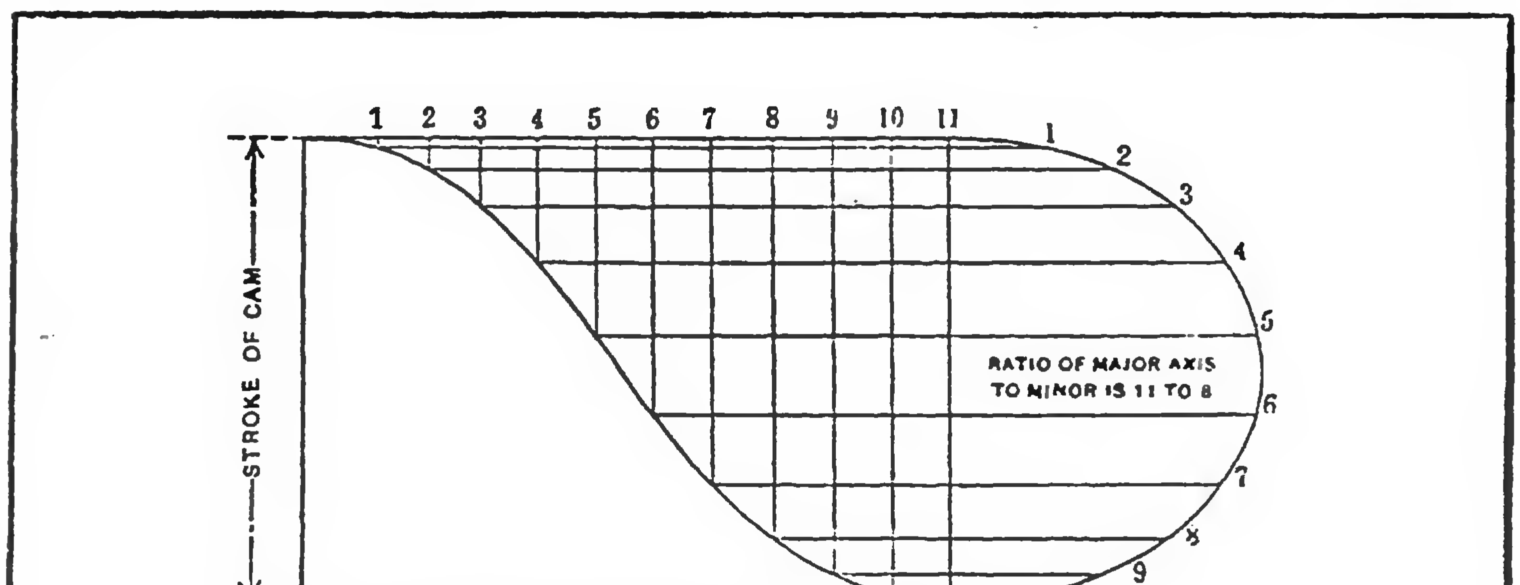
or retardation bearing the same ratio to the speed as the acceleration or retardation produced by gravity; hence its name. A very close and satisfactory approximation for the gravity curve, and one that entails less work than the theoretical, is shown by the diagram. The method of drawing is similar to the one used for harmonic motion, excepting that an ellipse takes the place of the semi-circle. It can be seen very readily that the ratio of the major and minor axes will determine the character of the cam curve. To obtain a curve that will approximate the gravity curve, the line representing the stroke of the cam should be used as the minor axis and the ratio of major axis to minor axis should be 1⅜ to 1 or 11 to 8. By dividing the semi-ellipse and line of angle of motion into the same number of equal parts, and projecting, points on the curve are obtained.

Gravity Idler. The gravity type of idler used in conjunction with many belt drives, consists of a weighted idler pulley, so pivoted from a long arm that the idler runs near the small pulley against the loose side of the belt, in such a way as to increase the arc of contact of the belt on this pulley. These idlers are of especial value on difficult drives where there is a large difference in the diameter of the driver and driven pulleys.

Gray Cast Iron. See Cast Iron.

Green Brass. When brass contains from 20 to 25 per cent of zinc, it has a greenish-yellow color. Because of this color it is known as "green brass."

Green Sand Core. A part of a foundry mold inserted in the mold cavity so as to form either a hole or a recess in the casting; made from ordinary green molding sand and not dried or baked.



Approximate Gravity Curve

This is the cheapest kind of core that can be used for molding, but can only be used for plain cylindrical shapes or for patterns having such recesses that the core can be shaped in the molding sand in connection with the regular molding work.

Gridiron Valve. This is a multiple-port type of engine slide valve designed to give a maximum opening with minimum travel. Both the valve and its seat contain a number of narrow openings or ports, so that a short movement of the valve will open or close a comparatively large opening. For example, if the steam valve has twelve openings, each ¼ inch in width, a movement of ¼ inch of the valve will open a space $12 \times \frac{1}{4} = 3$ inches in length.

Grinders, Floor-Stand Type. This type of machine is used for "hand grinding" and the grinder head is supported by a pedestal or floor stand. Machines of this type generally mount two wheels—one on each end of the spindle. Floor stands generally mount grinding wheels from 12 to 24 inches in diameter and from 2 to 4 inches thick. The spindle may be driven by a belt or the stand may be a self-contained machine, with an electric motor at the center, whose shaft is also the wheel spindle. The stand should be equipped with adequate wheel guards, to protect the operator against wheel breakage, and which can at the same time act as dust hoods if properly connected to an exhaust system. Castings weighing from 2 to 50 pounds are usually snagged on floor stands. For smaller pieces weighing two pounds, or less, it is more economical to use bench stands. They are similar in construction in every way to floor stands, but are smaller and have no pedestal.

Grinders, Portable Class. Grinders which may properly be included in the portable class are made in quite a variety of forms.

A type which is used for many different purposes is commonly known as a "toolpost grinder," owing to the fact that it is held in the toolpost of a machine like the lathe, planer, or shaper. Modern grinders of this class are electrically driven, the motor being connected directly in the grinding wheel. The current is supplied ordinarily from a lamp-socket, connections being made with an ordinary lamp cord. These toolpost grinders are very often used for truing lathe centers, grinding small work in lathes (when a regular grinding machine is not available), and they also enable the planer or shaper to be used for grinding plane surfaces. When used for this purpose, the grinder is clamped in the toolpost in such a position that the axis of the grinding wheel is parallel with the surface to be ground, and the revolving wheel is used in practically the same way that a tool would be used for planing.

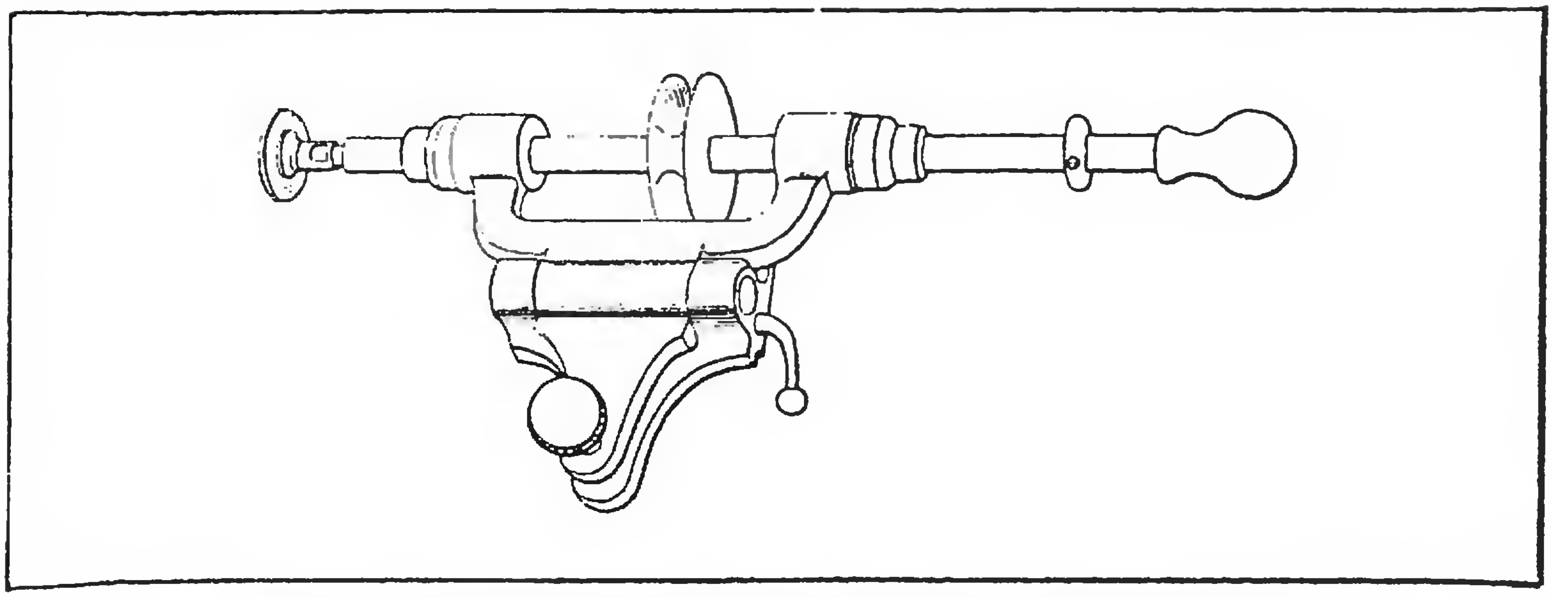
Hand-manipulated Type: Small portable grinders of the hand

type are used for finish grinding miscellaneous parts or surfaces which, because of their shape or location, require a small grinding wheel and hand manipulation. Such grinders are used extensively in diemaking for grinding out cavities or other surfaces. They are applied to various dies used in forming sheet metals and also in finishing certain cavities or passages in diecasting dies, metal patterns, etc. There are several types of these small portable grinders. Some are driven by electricity, others by air, and there is also the flexible-shaft type. Grinding wheel manufacturers make special shapes of small wheels for use in these portable grinders. These wheels are made in the form of disks, cones, and in cylindrical, spherical and other shapes. Portable grinders greatly simplify the machining of many cavities or other surfaces, especially if the part has been hardened.

Grinders, Swing-Frame Type. The swing-frame grinding machine was designed for the purpose of removing the fins, gates and nails left by and in molding, from castings too heavy to be conveniently lifted by hand. One wheel only is mounted on a machine, and the arm on which the wheel is mounted has a large radius of swing, as well as being designed to travel laterally on a track. Swing frame machines are the heavy-duty machines in the foundry and are rigidly constructed. Great pressures of wheel on work are possible because the operator bears his whole weight at times on the handles of the machine. Wheels from 12 to 18 inches in diameter and from 2 to 3 inches thick are commonly employed.

Grinding Allowances. The amount of stock that can economically be removed by grinding depends largely upon the size and power of the grinding machine. The modern practice, when using heavy machines, is to reduce the work in a lathe to within somewhere between 1/64 and 1/32 inch of the required diameter and then finish by grinding. The lathe is simply used for roughing, and the stock is removed by taking one or more coarse cuts, leaving a rough surface on the work. It is practicable, in many cases, to grind bar stock from the rough without any preliminary turning operation, although most work is first turned. In using a light grinder, the allowance for grinding must be comparatively small and is governed more or less, in any case, by the size and character of the work, as well as by the power and stock-removing capacity of the grinding machine. The grinding allowance for parts which have to be hardened naturally depends, to some extent, upon the shape of the part and the liability of distortion due to the hardening process.

Grinding Attachments, Push-Spindle. As the bench lathe is



Push- or Traverse-spindle Grinding Attachment

used almost exclusively for fine precision work, it is necessary, in many cases, to finish bored holes and exterior surfaces by grinding. A typical design of an internal grinding attachment for the bench lathe is shown by the illustration. The spindle, which is free to move in a lengthwise direction, is held by two bearings, and, when grinding, it is traversed by hand. This device is sometimes called a *push-spindle grinding attachment*. The spindle is driven by a round belt from an overhead countershaft. The handle at the end of the spindle, which is simply a loose knob, is usually held between the thumb and the index finger, and the sensitive touch secured in this way enables a skilled workman to determine if he is working under proper conditions, as soon as the wheel comes into contact with the work.

Grinding Attachment, Toolpost. This type of grinding attachment is used on lathes for light grinding operations and, in some cases, for very light milling or other machining operations on gages, jigs, dies, etc. The attachment is held by a shank that is clamped in the regular toolpost and its spindle is driven by a small motor.

Grinding, Form. See Form Grinding.

Grinding Machines. Grinding machines were used originally almost exclusively for truing tool steel parts which had been distorted by hardening, and are still indispensable for work of this class. The great improvements which have been made, both in grinding machines and abrasive wheels, however, have resulted in the application of the grinding process to the finishing of a great many unhardened parts. In either case, the work, as a rule, is first reduced to nearly the required size by turning in some form of lathe, and then it is ground to the finished dimension. After a part has been hardened, grinding is the only practicable method of truing it. On the other hand, unhardened pieces can

be finished by other means, but grinding is preferable for most cylindrical work, because it enables parts to be finished accurately to a given diameter in less time than would be required by any other known method. Many different types of grinding machines have been developed for handling the various kinds of work to which the grinding process is applicable. The machines used for grinding cylindrical parts, such as shafts, piston-rods, etc., are called *cylindrical grinders*, whereas the type used for grinding holes in bushings, gears, milling cutters, etc., are known as *internal grinders*. There are also *surface grinders* for finishing flat or plane surfaces, and, in addition, types that are designed for specific kinds of work. The first commercial grinding machine, built in 1864-1865, was used only as a precision machine for grinding hardened parts and correcting slight errors due to warping in hardening. From this small beginning, the grinding machine has passed through a remarkable development. See type of machine as, for example, Cylindrical Grinding Machines; Centerless Grinding; Disk Grinders; Internal Grinding Machines; Surface Grinding Machines.

Grinding, Plunge-Cut. See Plunge-cut Grinding.

Grinding Screw Threads. See Thread Grinding.

Grinding Wheel Bonding Processes. See Bonding Processes for Grinding Wheels.

Grinding Wheel Bushings. Most grinding wheels are bushed to size with lead, babbitt, or other soft material, the exception being very small wheels, and very large wheels which are to be held in a chuck or in some way other than by flanges on a spindle. The bushing process follows that of truing. The bushing must be true with the sides of the wheel, otherwise the wheel may break when placed on the spindle and the flanges tightened. The diameter of the hole should be from 0.002 inch to 0.005 inch larger than the diameter of the spindle on which the wheel is to be mounted. If the hole is smaller, breakage may occur by forcing the wheel. If the hole is larger than this limit it is difficult to mount the wheel so that it will run true and straight, and, too, it may be clamped in the flanges in such a position as to be out of balance. Lead is the most commonly used material for bushing. Babbitt, being a little harder, is better for the severe duty to which coarse wheels and large cup wheels are subjected. If the lead is too soft, the bushing will not retain its shape and will be easily damaged in mounting.

Grinding Wheel Care. Wheels used in wet grinding should not be allowed to stand partly immersed in water. The water-soaked portion may throw the wheel dangerously out of balance.

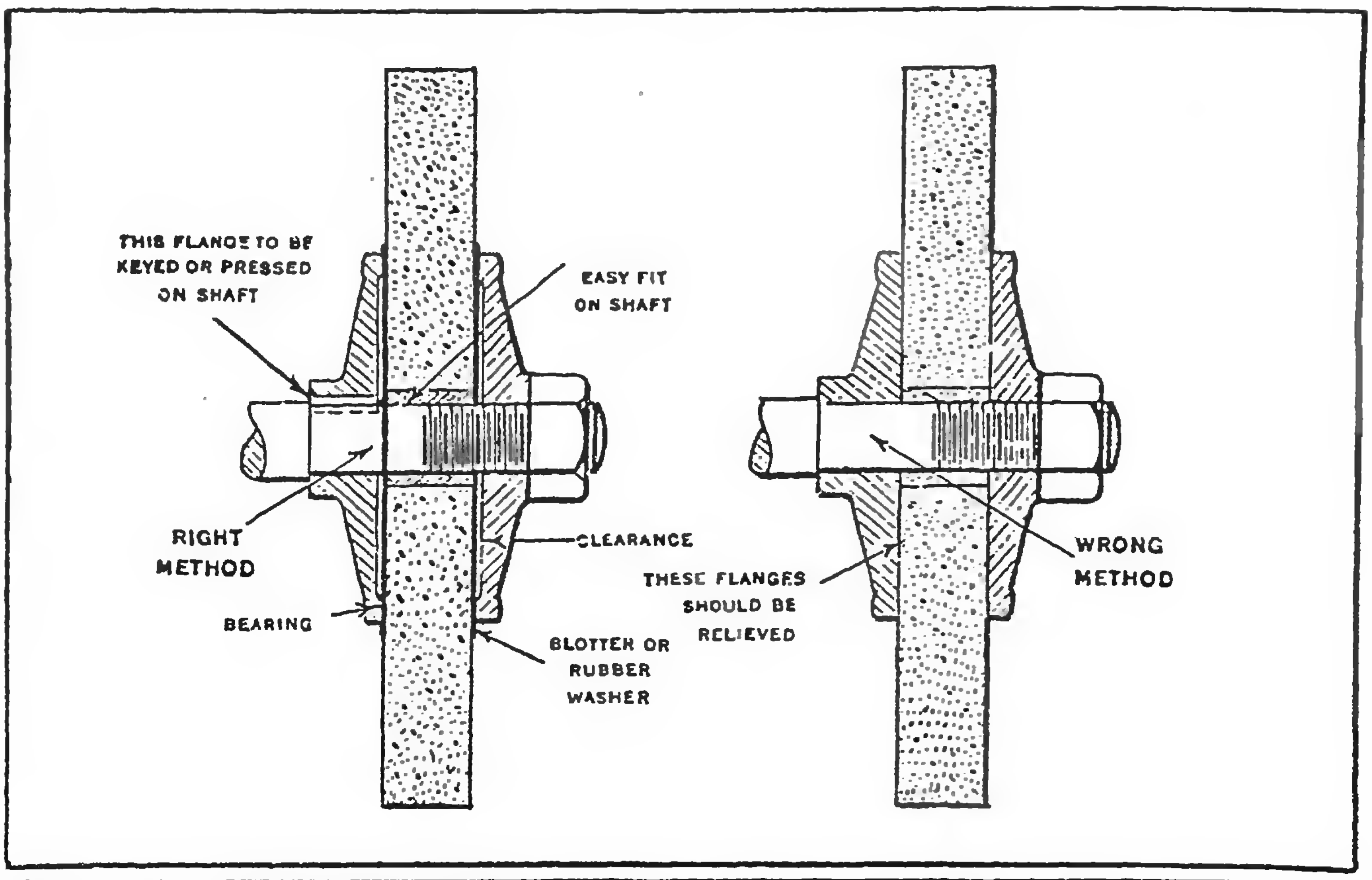
All wet tool grinders that are not so designed as to provide a constant supply of fresh water should be thoroughly drained at the end of each day's work, and a fresh supply of water provided just before starting.

Grinding Wheel Colors. The color of both aluminum-oxide and silicon-carbide grinding wheels depends on the material used to hold the abrasive particles together, which is termed the "bond." The exact shade, however, is likely to vary somewhat with wheels of the same bond that are produced in the same heat, and so a slight variation in the shade of two wheels does not necessarily indicate a difference in grade. The four most important bonding processes are known as the vitrified, silicate, elastic, and rubber processes, and these names are applied to the grinding wheels produced by them. The use of different bonds permits the manufacture of wheels of different characteristics to suit all classes of grinding. Vitrified wheels are standard for most grinding operations, the other kinds being used when special conditions are encountered. Probably 80 per cent of all grinding wheels are vitrified. Vitrified wheels can be readily distinguished from the other wheels by their reddish or reddish-brown color, and the clean ringing sound which results when they are tapped. Silicate wheels are easily recognized by their light gray color. Elastic and vulcanized wheels are almost black, but they may be distinguished by their odor when subjected to the friction of a grinding operation or when a small part is burned. Elastic wheels emit an aroma, whereas rubber wheels give off the odor of burning rubber.

Grinding Wheel Grade and Grain. The term "grade," as applied to a grinding wheel, refers to the tenacity with which the bond holds the cutting particles or abrasive grains in place, and not to the hardness of the abrasive. A wheel from which the abrasive grains can easily be dislodged is called "soft," or of "soft grade," and one which holds the grains securely is referred to as a "hard wheel." By varying the amount and composition of the bond, wheels of different grades are obtained.

Grades are indicated by letters of the alphabet from A to Z. Wheel grades from A to Z range from soft to hard. The standard marking also includes the symbols for the kind of abrasive, grain size, structure or density, and bond or process.

The grain sizes commonly used and varying from coarse to fine are indicated by the following numbers: 10, 12, 14, 16, 20, 24, 30, 36, 46, 54, 60, 70, 80, 90, 100, 120, 150, 180, and 220. The following additional sizes are used occasionally: 240, 280, 320, 400, 500, and 600. See also Abrasive Grit Number.



Correct and Incorrect Method of Mounting Grinding Wheels

Grinding Wheel Mounting. Grinding wheels should fit freely on their spindles but without unnecessary play. If a wheel is forced onto the spindle, there is danger of starting cracks. The diameter of the flanges should be one-half the wheel diameter (never less than one-third), and the flanges should be relieved or recessed to secure an annular bearing at their circumference. (See illustration.) The inner flange should be keyed or shrunk onto the spindle. Compressible washers of blotting paper or rubber should be placed between the wheel and the flanges, to distribute the clamping pressure evenly. The flanges should be clamped just tight enough to hold the wheel firmly. Wheels should be carefully inspected, and be tapped lightly before mounting, as new wheels occasionally burst when first brought up to speed, because of hidden cracks resulting from rough handling in transit.

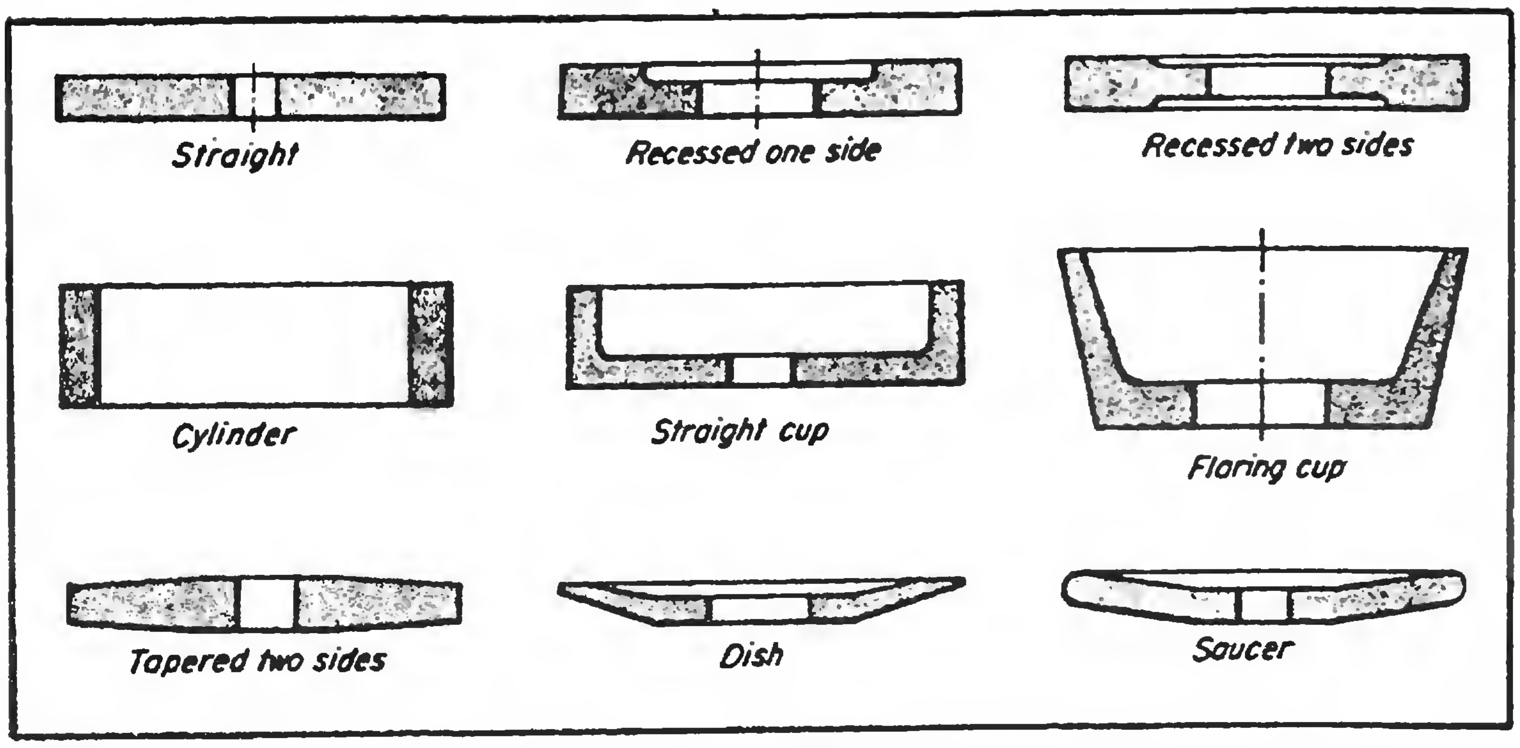
The right and wrong methods of mounting grinding wheels are shown by the illustration. The right method requires the use of relieved flanges with compressible washers between the wheel and flange. The relieved flanges give a bearing on the outer edge and the washers distribute the pressure evenly when the flanges are tightened, by compensating for any imperfections or unevenness in either wheel or flange. When the flanges are straight and no washers are used, tightening the spindle nut tends to concentrate the pressure near the center of the wheel instead of distributing it over the entire flange surface, thus creating a dangerous condition. The hole through the wheel bushing should be about 0.005 inch larger than the size of the spindle so that the wheel

will slide on without cramping, but still have a fairly good fit on the spindle as well as against the inside flange.

Ends of grinder spindles should be so threaded that the nuts on both ends will tend to tighten as the spindles revolve. Care should be taken in setting up machines to see that the spindles are arranged to revolve in the proper direction, or else the nuts on the ends will loosen. To remove the nuts, they should both be turned in the direction in which the spindle revolves when the wheel is in operation.

Grinding Wheel Selection. In selecting wheels for grinding metals, the physical properties of the metals to be ground serve as a basis for determining whether to use silicon carbide abrasives or the aluminous abrasives. (For information about these two general classes see Abrasives.) The silicon carbide abrasives represented by crystolon, carborundum, etc., differ materially from the aluminous abrasives such as alundum, aloxite, etc. The grains of the former are harder but are also more brittle due to the structure; the grains of the latter, while not as hard, are tougher and do not break apart as easily, thus being able to withstand a greater stress. In addition, the aluminous abrasives admit of a certain range of toughness in their manufacture. On account of the difference in physical characteristics of the two abrasives, a general rule has been established, namely, that aluminous abrasives are used for grinding materials of high tensile strength, and silicon carbide abrasives for those of lower tensile strength. While tensile strength alone is not the criterion, inasmuch as hardness and ductility influence the selection, experience has shown that, in general, the aluminous abrasives are particularly adopted for grinding materials of high tensile strength. For information about different grinding wheels, see kind of wheel as, for example, Elastic Grinding Wheels; Vitrified Grinding Wheels; Vulcanite Grinding Wheels.

Grinding Wheel Shapes. Grinding wheels come in many shapes as shown in the accompanying figure. The chief distinction between them is whether they grind on the periphery (straight cylindrical wheel) or on the end face (cup wheel). Straight cylindrical wheels are the kind generally used in connection with cylindrical grinding operations. Wheels of this form vary greatly in size, diameter, and width of face, depending upon the class of work for which the wheel is used and the size and power of the grinding machine. Quite large wheels are used on heavy work. In connection with form grinding, the wheel-face is frequently made wide enough to cover the entire surface of the work; that is, the wheel is dressed to conform to the shape required on the work and the latter is ground by feed-



Nine Shapes of Grinding Wheels that will Perform Most Jobs

ing the wheel straight in, there being no lateral or transverse movement. Very thin or narrow wheels are sometimes used in connection with cutter or reamer grinding or for cutting off stock.

The saucer or dish-shaped wheels are extensively used for grinding formed milling cutters, etc. especially on regular tool- and cutter-grinding machines. The cup wheel is used for grinding flat surfaces by traversing the work past the end or face of the wheel. The cylinder wheel is also used for producing flat surfaces, grinding being done by the end, the same as with a cup wheel. The latter is attached directly to the spindle but the cylinder wheel is held in a special chuck.

There are other grinding wheels called cones and plugs, with various shapes, that have a blind hole threaded bushing for mounting.

Grinding Wheel Speeds. The peripheral speed of a grinding wheel is usually between 5500 and 6000 feet per minute, but speeds varying from 5000 to 7000 feet per minute are employed. Plain grinding wheels may safely be operated at higher speeds than cup-wheels or those of special shapes; hard wheels may also be run at a higher speed than soft ones. It is the custom of grinding wheel manufacturers to attach a label to each wheel indicating the safe maximum speed for that particular shape and grade of wheel. These recommended speeds should never be exceeded. A committee appointed by representative abrasive wheel manufacturers, in order to determine safe practices in the use of grinding wheels, recommended the following speeds: A peripheral speed of 5000 feet per minute for vitrified and silicate straight wheels, tapered wheels, and shapes other than those known as cup- and cylinder-wheels, which are used on bench, floor, swing-

frame, and other machines for rough-grinding. Speeds exceeding 5000 feet may be used upon the recommendation of the wheel manufacturer, but in no case should a speed of 6500 feet per minute be exceeded. A speed of 4500 feet per minute was recommended as the standard operating speed for silicate and vitrified wheels of the cup and cylinder shape, used on bench, floor, swing-frame, and other machines for rough-grinding. For elastic, vulcanite, and wheels having other organic bonds, the recommendations of individual wheel manufacturers should be followed.

Grinding Wheel Standards. Grinding wheels in nine standard shapes, and in a range of sizes for each shape, have been standardized by the Grinding Wheel Manufacturers Association of the United States and Canada. These nine shapes represent practically all of the forms used on standard makes of grinding machines. This standard not only simplifies the stocking of wheels but enables the user to identify accurately any wheel by giving the type number and the important dimensions. The No. 1 or straight type is made in diameters ranging from 1/4 inch up to 36 inches and in thicknesses from 1/4 inch up to 4 inches. For internal grinding, this type of wheel is made in diameters from 1/4 inch to 4 inches and in thicknesses from 1/4 inch to 2 1/2 inches. Complete tables giving the diameters and other dimensions for the nine standard types or shapes will be found in engineering handbooks.

Grinding Wheel Truing. See Diamonds for Wheel Truing.

Grindstones. Most of the grindstones used in the United States come from Huron, Mich.; Berea, Ohio; or from Grindstone Island, Nova Scotia. All of these localities produce several grades. Most Berea stones are rather coarse; those from Nova Scotia are of all grades. Grindstones are natural sand stones, and the cutting material is oxide of silicon (SiO_2), or quartz sand, as it is commonly called. Grindstones are softer when wet than when dry, and they should never be left standing with one side in the water, because, when the stone is again used, this side will be worn away faster than the other.

Mounting: The tendency for cracks to start in grindstones can be overcome by a proper method of mounting. It is good practice to fill the central space around the arbor with cement or lead after the stone is centered. Wooden wedges should never be used. The stone should be supported by flanges of generous proportions, and wooden washers from 1/2 to 1 inch in thickness (or a double thickness of leather or rubber) should be inserted between the flanges and the stone to compensate for surface inequalities.

Speeds: The grindstones used in machine shops usually have a surface speed varying from 800 to 1000 feet per minute, although

these speeds are exceeded considerably in some instances. Cutlery concerns sometimes run grindstones at 3000 or 4000 feet per minute. The safe maximum speed is difficult to determine, because stones from the same quarry vary in strength. As a rule, the speed should be limited to 2500 feet per minute, if the variety of the stone is not known.

Grip Socket. This is a type of drill socket designed to hold and drive taper shank drills and other tools provided with taper shanks. A groove is milled in the shank of the drill or tool, and a key is let into the body of the socket which fits into the groove and is locked securely in place by turning a revolving collar one revolution. When the key is locked, it is impossible for the tool to slip in the socket or to be pulled out until the collar is turned back again to release the key. In the grip socket, the taper shank is not depended upon to act as a driver, but the key takes the thrust.

Grooving. In boilers, grooving is a condition similar to "pitting," consisting of the formation of grooves in the boiler plates. It is an injury especially dangerous because the grooves may become covered with scale and are, therefore, difficult to locate. It is caused partly by chemical action from oxygen and chlorine released from the feed water, and partly by mechanical action, such as excessive calking, which impairs the surface of the metal and exposes it to the corrosive elements in the feed water.

Ground Stone. What is known as "ground stone" is used by some small tool manufacturers for lapping plug gages, ring gages, etc., and this material is also used, to some extent, in connection with watch manufacture, for fine lapping operations. "Hindostan powder" is produced from a very fine sandstone which is quarried in Indiana. Another ground stone known as "Turkey powder" is composed of pulverized Turkish oilstones, which are imported. An expensive grade of ground stone is known as "Arkansas powder"; it is pulverized Arkansas rock and is quarried in Arkansas. The Turkey powder and Arkansas powder have been used quite extensively in connection with watch manufacture.

Guerin Process of Metal Forming. This process is employed in the aircraft and other industries for blanking or forming and shallow drawing of sheet metal parts by subjecting the sheet of material to a high pressure while it is pressed between a confined rubber pad or blanket on one side and a die (or punch) of the required shape on the other side. The rubber forces the sheet to conform to the shape of the opposing die. This process is applicable to materials such as aluminum or magnesium alloys and in some cases to sheet steel. In producing comparatively small parts, the press may be equipped with several dies so that

either duplicate or different parts are formed simultaneously or at one stroke of the press. As a rule, large hydraulic presses are employed but mechanical presses are adaptable for some classes of work. The press used may be equipped with two or more tables to permit loading or unloading while one table is in the forming or operating position. The dies may be made of such materials as zinc alloy, Masonite, aluminum alloy, magnesium, and steel in special cases. The selection of the die material depends upon the size of the work and general character of the forming operation. Some dies are of laminated construction and are built up to the form and shape required, whereas others, such as those made of zinc-base alloys, are cast to shape and then finished with a little grinding or polishing. These cast dies may be recast when some new die is required. The low die cost is one of the advantages of the process. The rubber pad takes the place of the mating die member. It is important to use rubber having the right degree of hardness. This hardness, as determined by a Shore Durometer, would ordinarily be about 50 to 60 for drawing, 65 to 70 for forming, and 75 to 80 for shearing operations. Synthetic rubber is not suitable for this process.

See also Marforming.

Guest's Formula. A formula known as "Guest's formula" was proposed in 1900 by J. J. Guest as the results of experiments made by him on combined bending and torsion. According to this formula:

$$\text{Combined moment} = \sqrt{M_b^2 + M_t^2} = S_s Z_p.$$

In this formula M_b = maximum bending moment; M_t = maximum torsional moment; S_s = permissible working stress in shear; Z_p = polar section modulus. This empirical formula is applicable to parts of circular cross-section and when such material as mild (machine) steel is used.

Guldinus Rules. The Guldinus or Pappus rules provide a means by which the area of any surface of revolution and the volume of any solid of revolution may be found. Briefly stated, these rules are: 1. The area of the surface generated by any line rotating about a fixed axis of revolution equals the length of the line multiplied by the length of the path of its center of gravity. The generating line must lie wholly on one side of the axis of revolution and must be in the same plane as the axis. 2. The volume of a solid body formed by the revolution of a surface about a fixed axis equals the area of the surface multiplied by the length of the path of its center of gravity. The surface must lie wholly on one side of the axis of revolution and must be in the same plane as the axis.

Gulleting File. This file is made of round section in the blunt shape. It is single-cut and used principally for extending the gullets of the teeth of what are known as the "gullet-tooth" and "briar-tooth" saws.

Gunite. Gunite is a strong wear-resisting cast metal which is used for various machine parts such as cams, rails, and miscellaneous wearing surfaces, and also for locomotive cross-head shoes, cylinder and valve bushings and rings, and for certain automotive parts such as brake drums, clutch pressure plates, etc.

Gun Lathe. Gun lathes are designed for turning or for turning and boring naval and coast defense guns, and are sometimes known as *turning and boring lathes.* Comparatively small lathes of this class, such as are used for turning five- or six-inch guns, are often designed along the same general lines as an engine lathe. The larger lathes, however, differ from the engine lathe, both in regard to the design of the bed, the method of imparting feeding movement to the carriage, etc. These larger sizes usually have three or four shears on the bed, and two tool carriages instead of one.

Gun-Metal. Gun-metal or gun-bronze consists of about 90 per cent of copper and 10 per cent of tin with small percentages of lead, iron, and zinc. Gun-metal is used as a bearing metal and for a great many parts, such as valves, valve seats, flanged pipe fittings, etc., where exposed to the action of sea water. The composition follows: Copper, from 87 to 89 per cent; tin, from 9 to 11 per cent; zinc, from 1 to 3 per cent; iron, not exceeding 0.06 per cent; and lead, not exceeding 0.2 per cent. The mixture formed of copper, 88 per cent; tin, 10 per cent; and zinc, 2 per cent, is variously known as "zinc bronze," "Admiralty metal," "government-bronze," and "88-10-2 alloy," although these terms are also frequently applied to all gun-metals. The castings made from gun-bronze are improved by the addition of a small amount of zinc, and the alloy is made harder by the presence of a small percentage of iron, while the small percentage of lead present makes an alloy that is more easily machined. The tensile strength of gun-bronze is from 25,000 to 35,000 pounds per square inch. The elastic limit varies from about 15,000 to 17,000 pounds per square inch, and the metal withstands severe shocks without fracture. The minimum elongation should be about 15 per cent in 2 inches.

Gun-Metal Finish on Aluminum. The gun-metal finish can be given aluminum by immersing it for from six to ten seconds in a cold solution of 12 parts of hydrochloric acid; 1 part of chloride of antimony; and 87 parts of distilled water. After that, thoroughly wash it in running water for several minutes, dry

with heat, and lightly buff with a high-speed wheel. The color penetrates the metal and its depth is governed by the length of time it is immersed. If immersed longer than ten seconds, the solution should be weakened, as hydrochloric acid "eats" the metal.

Gun-Metal Finish on Steel. The first operation in obtaining a gun-metal finish is to thoroughly clean the work by methods that will not injure the surfaces. Grease and dirt are readily removed by boiling the work in a solution of one pound of potash to one gallon of water. The potash will last a long time and the water can be replenished as it boils away. When exhausted, the bath can be renewed by adding fresh potash. Scale, oxide, etc., are not removed by washing methods and, hence, a pickling in acid solutions is required. Polished steel surfaces can be pickled by immersing them, in contact with a piece of clean zinc, in a moderately strong solution of the acid potassium sulphate and water. Hydrogen gas is liberated when the zinc decomposes the solution, and this removes the oxide of iron or rust from the steel. Another good pickling solution for steel is made of 20 parts of hydrochloric acid and 80 parts of water. Iron and steel can also be pickled white, in concentrated nitric acid to which has been added some lampblack. After pickling, the work should always be thoroughly washed and scratch-brushed.

Solutions for Gun-metal Finishes: Several different chemical solutions have been used successfully in giving steel the gun-metal finish or black color. Among these are the following: Bismuth chloride, 1 part; copper chloride, 1 part; mercury chloride, 2 parts; hydrochloric acid, 6 parts; and water, 50 parts. Ferric chloride, 1 part; alcohol, 8 parts; and water, 8 parts. Copper sulphate, 2 parts; hydrochloric acid, 3 parts; nitric acid, 7 parts; and perchloride of iron, 88 parts. Other solutions have been prepared from nitric ether, nitric acid, copper sulphate, iron chloride, alcohol and water, and from nitric acid, copper sulphate, iron chloride, and water.

The method of applying these solutions and finishing the work is practically the same in all cases. The surface of the work is given a very thin coating with a soft brush or sponge that has been well squeezed, and is then allowed to dry. If put on too thick the surface will be unevenly corroded and white spots will appear. The work is then put into a closed retort to which steam is admitted and maintained at a temperature of about 100 degrees F. until covered with a slight rust. It is then boiled in clean water for about fifteen minutes and allowed to dry. A coating of black oxide will cover the surface, and this is scratch-brushed. After brushing, the surface will show a grayish black.

By repeating the sponging, steaming, and brushing operations several times, a shiny black surface will be obtained that is lasting. For the best finishes these operations are repeated as many as eight times.

Gunter's Chain. Gunter's chain is a chain used by surveyors for land measurements. It has 100 links, each 7.92 inches long. The total length of the chain is 66 feet, or 4 rods. The handles and the center of the chain are fitted with swivels to prevent kinking. At every tenth link from either end is attached a brass tag with one, two, three, or four prongs to assist in the reading of the measurements. The fifty-link mark is round, so as to be easily distinguished from the others. This chain is not used as much as formerly. See also Engineer's Chain.

Gurley's Bronze. Gurley's bronze is used for the framework for surveyors' instruments, and similar purposes. It contains 16 parts of copper; 1 part of tin; 1 part of zinc; and ½ part of lead. The tensile strength is about 40,000 pounds per square inch; the elongation, about 25 per cent in 2 inches; and the specific gravity, about 8.7.

Gutta-Percha. Gutta-percha is derived from the secretions of the bark of certain trees found in the Straits Settlements and the Malaccan Archipelago. At temperatures between 32 and 80 degrees F., it resembles dark brown leather; at temperatures above 80 degrees F., it softens; and at 150 degrees F., it becomes plastic and can be molded. Upon cooling, it again becomes nonplastic. It oxidizes when exposed to the air, changing its color and becoming brittle. The chief use of gutta-percha is for electrical insulating purposes. It appears in commerce in the forms of blocks or cakes of a grayish appearance. When used for insulation, it is shredded into warm water, kneaded, strained, and rolled into sheets. It is applied to the wire that is to be insulated by special tubing machines, or wound upon the wire in the form of strips. Gutta-percha may be used as an insulating material in the pure state, without admixtures of any kind. It is less porous than rubber, and is therefore more waterproof. For this reason, it is the best material to use as an insulation for submarine cables. Its specific gravity is almost exactly equal to that of water.

Gypsum. Gypsum is a sulphate of lime. It is the same as calcium sulphate, commonly known as plaster-of-paris. See Calcium Sulphate.

Gyration Radius. See Radius of Gyration.

Gyroscope. The gyroscope may be defined, in general, as a mechanism in which a rotating wheel or disk is mounted in

gimbals so that the principal axis of rotation always passes through a fixed point. The gyroscope possesses the peculiar quality of resisting any angular displacement of its axis after it has once been set in motion; hence, it is used for securing equilibrium in a great number of devices. Gyroscopes are applied as stabilizers. The gyroscope is also used in a special type of gyroscopic compass which has been highly successful.

H

Hackett K-Copper. A copper alloy especially suitable for use in welding equipment—as for welding tips and holders. Welding tips made from this alloy are said to mushroom less easily than those made of pure copper, require less frequent dressing, and give a greater number of welds during their life. This alloy combines the physical properties of steel and bronze with the high electrical and heat conductivity of copper. In the drawn rod form, it possesses about 83 per cent of the electrical conductivity of pure drawn copper, and in the forged form, 75 to 85 per cent that of forged copper. Hardness, 70 to 80 Rockwell B (125 to 150 Brinell); ultimate tensile strength, 70,000 pounds per square inch.

Hacksaw Blades. The straight-tooth blade is generally preferred for power hacksaw machines, although hacksaw blades are made with hook teeth and other forms having positive and negative rake. The objection to the hook-tooth blades is that they "hog in" or bury their teeth whenever they come in contact with edges or walls of the work having an acute angle. Blades having negative rake teeth require more pressure in cutting, but they are often of advantage for cutting parts having thin walls, and in general for work that presents little or no resistance to the pressure of the teeth. The most commonly used pitches are 10 and 14 teeth per inch. The 10-pitch blades are used to cut heavy cross-sections, while the 14-pitch blades are used for medium and light work. On the extremely hard materials of small cross-section, where a heavy pressure must be applied, a fine-pitch blade is necessary, so that the pressure can be distributed over enough teeth to prevent the points of the teeth from crumbling under the pressure. On the other hand, in soft metals, blades of a coarser pitch provide chip space for the larger and heavier chips that a heavy-blade pressure produces in the softer metals.

Tests have shown that steel for saw blades should contain from 1.00 to 1.25 per cent carbon, 0.55 to 2.00 per cent tungsten, 0.20 to 0.50 per cent manganese, 0.20 to 0.80 per cent chromium, and about 0.25 per cent vanadium. Another well-known manufacturer of saw blades keeps the carbon content between 0.80 and 0.90 per cent, but increases the tungsten content from 2.00 to 3.60 per cent, thereby obtaining what is claimed to be an unusually tough and hard blade. The high carbon content blades are not so suitable for high tension as the medium carbon blades; but they are often

found to cut better under medium pressures and high cutting speeds, while the lower carbon content blades often cut best on materials that call for a heavy feed or pressure, but a medium or low cutting speed.

High-carbon blades are recommended for mild steel, where high speed and medium pressure is used, and the lower carbon blades with higher tungsten content for alloy steels, where medium cutting speed and heavy pressures are used. If a great deal of sawing is done in one class of steel, the maximum cutting speed may be determined as follows: Increase the cutting strokes per minute, by 5 for each piece cut off until the temper is drawn in the blade in spite of the cooling lubricant. Then reduce the cutting strokes per minute, about ten strokes, and the most efficient cutting speed has been obtained.

Hacksaw Cutting Speeds. As the cutting action of a hacksaw is not continuous and the speed is not uniform, the average cutting speed in a power hacksaw machine should be considered. Approximately, the cutting speed of the first and last quarters of the stroke may be assumed to be one-half the speed of the stroke in the second and third quarters. For example, assume that the hacksaw has a 6-inch stroke. Then the first 1½ inches of blade travel is accomplished at half the speed of the next 1½ inches of travel, which completes half the stroke. The third 1½ inches of blade travel is accomplished at the same speed as the second, and finally the fourth and last 1½ inches of travel is again accomplished at one-half the speed of the two middle fourths; or briefly, the middle 3 inches of the stroke is traveled at an average speed of twice that of the ends, and this is the cutting speed to be reckoned with.

Lay out a half circle, and connect each end of the half circle by its diameter. Divide the arc of the half circle into three equal spaces. Project the division points down to the diameter, and it will be seen that the length of the middle space, measured on the diameter, is twice the length of the end spaces. The two middle fourths of the stroke are traveled in one-third of the half-circle or in one-sixth of the time required for one complete revolution of the crankshaft. Hence, if the saw blade continued to travel at the same cutting speed as it does during the middle three inches of the stroke for an entire revolution of the crankshaft, it would travel six times three inches, or eighteen inches per revolution. From this we obtain the cutting speed in feet per minute as equal to R. P. M. of crankshaft $\times \frac{6 \times 3}{12}$. For example if the crankshaft is running at 100 revolutions per minute, and the stroke is 6 inches, the cutting speed would be 150 feet per minute; at 80 revolutions per minute, it would be 120 feet per minute;

and at 50 revolutions per minute, 75 feet per minute. When a given cutting speed in feet is required on a machine having a 6-inch stroke it is only necessary to see that the revolutions per minute of the crankshaft or the cutting strokes per minute equal two-thirds of the cutting speed expressed in feet. Assume that for a given case a cutting speed of 90 feet would be satisfactory, when using a cutting lubricant. Then the cutting strokes per minute with a 6-inch stroke should be 60.

Hacksaw Machines. The power hacksaw machine, in its simplest form, merely provided means for reciprocating a hacksaw frame by mechanical power. Gradually, a great many improvements have been made in these machines, until now they constitute a distinct type in the machine tool class. The first improvement made in machines of this kind was to apply weights to give an adequate cutting pressure to the saw blade. The weight of the saw frame, in addition to sliding weights, is today utilized in several power hacksaw machines for obtaining varying pressures on the blade.

Another power hacksaw machine employs a ratchet feed. The blade pressure is varied by changing the compression of a spring that supplies the power for the ratchet fingers, this change being made through a lever on the side of the machine. Another power hacksaw machine is so designed that the blade pressure is applied mainly from an oil cylinder, the pressure in which is produced by a pump. The saw frame of still another design does not travel downward through an arc, but instead is mounted on a double-bearing slide, so that the blade always travels along parallel lines. The saw frame is brought down by means of a screw and nut mechanism actuated intermittently by a ratchet and pawl. Between the ratchet and the screw is located a friction disk that prevents excessive pressure from being exerted on the blade.

Hadfield's Steel. The steel known as Hadfield's steel contains about 12 per cent of manganese and from 0.8 to 1.25 per cent of carbon. This steel is very ductile and hard. The ductility of the steel is brought out by sudden cooling, the process being opposite to that employed for carbon steel. Hadfield manganese steel is used for car wheels, ore and rock crushers, mining machinery, and, in general, where a steel that will resist abrasion is required. It is very hard and cannot be machined with ordinary tools. Parts made from manganese steel are, therefore, cast and subsequently ground on the finished surfaces.

Hafnium. Hafnium is found in all zirconium minerals in amounts ranging from 2 to 20 per cent, and is sufficiently abundant to be available for commercial purposes. It is also present in so-called commercially pure zirconium oxide and salts

of zirconium. In chemical properties, it closely resembles zirconium. It has a very high melting point and high power of light emission.

Half-Nuts. The term "half-nuts" is applied to the two-part nut used on engine lathes for engaging and disengaging with the lead-screw. The half-nuts are opened or closed by a lever and are used to control the movement of the lathe carriage while cutting screw threads.

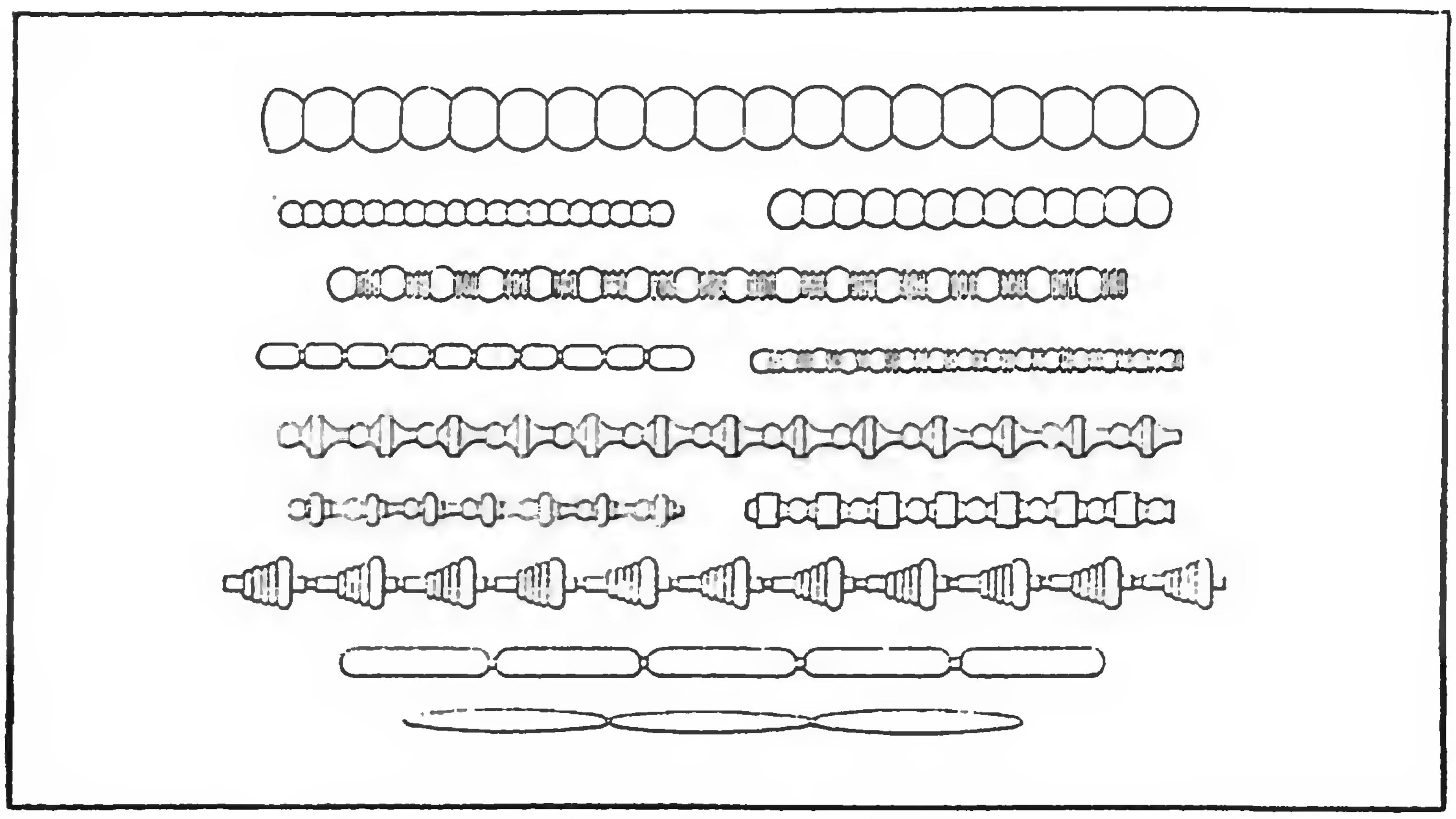
Half-Open Tailstock. This is a special design of tailstock for bench lathes in which the upper part of the spindle bearing is removed, so that the tailstock spindle may be readily lifted out of place. This tailstock is used on light delicate work when different tools are employed, the open construction enabling the spindle to be rapidly removed or replaced.

Half-Round Files. Such files do not form a complete semicircle, as the name implies, the arc being about one-third of the circle. Files of this class are double-cut and mostly bastard, although many are either second-cut, smooth, or dead smooth, the latter being used to a limited extent. Those having teeth finer than bastard are cut single on the convex side. This type is extensively used in machine shops, especially on curved surfaces.

Hammering Machines. Machine hammering, a process akin to swaging, plays an important part in the manufacturing processes in the jewelry and allied trades. A greater variety of work may be hammered than it is possible to swage, and, for this reason, the process is adapted to the forming of ornamental shapes, such as beaded work and jewelry parts, either from solid stock or tubing. The advantage of the process over screw machine production is threefold: Less material is required for the work, the resulting product is stronger on account of the compression of the metal, and the surface of the stock is not removed, thus making it possible to work rolled gold-plated wire and tubing. The hammering machine is not a competitor of the screw machine, although many classes of work can be done better by the hammering machine. The illustration conveys an idea of the range of work that may be done on hammering machines, and particularly shows the value of these machines in the optical and kindred trades. The hammering is done by means of two dies, one forming the anvil and the other the hammer proper. As blows are struck the action takes the form of a continuous vibration. On some classes of work, the upper die strikes 3600 blows per minute. In making dies for work that is to be separated, such as small ornaments or beads, the dies are left with a cut-off at one end, so that, as the work is moved forward in the dies, one section will be completed and cut off at each forward movement of the

stock. In all hammering dies, each succeeding pair of units of the design is slightly smaller than the previous pair nearer the end where the stock enters, so that each set of sections of the dies closes the metal down a little more until it is finished by the last set.

Hammers, Forging. Power hammers such as are used for general forging operations may be divided into two general classes: 1. Those which are actuated by a crank or eccentric that imparts motion to the hammer head through some form of mechanism designed to give the required resiliency or springing action. 2. Those which are operated either by steam or compressed air. Hammers of the first class mentioned are commonly designated



General Classes of Work Produced on a Hammering Machine

as *power* hammers in order to distinguish them from *steam* hammers, although they are all operated by power. Many power hammers such as are used on the lighter classes of forging work are of the vertical design.

Hammer Ratings: Forging hammers are rated in terms of the total weight of the falling or reciprocating parts, including the weight of the ram, piston-rod, piston, and the ram die with its key and dowel. Drop hammers of both steam and air-operated types are rated according to total weight of the ram, piston-rod, and piston, but the dies are not included for hammers of this type. The rating of board drop hammers is based on the total weight of the ram, boards, and the wedges which hold the boards in place in the ram. The weight of the dies is not included in the rating in this type as in other types of drop hammers.

From the foregoing it is evident that if a hammer has a rating of 1 ton this means that the falling or reciprocating parts weigh 2000 pounds, except that the weight of the ram die is omitted in the case of drop hammers. This method of rating hammers does not disclose the energy available, since this is affected by varying speed, stroke, ratio of anvil weight to falling weight, and steam conditions in the case of steam-operated hammers.

Hammer Weight. The ball peen hammers commonly used by machinists weigh from 1 to 1½ pounds. This weight does not include the handle, which is usually from 12 to 14 inches long and made of hickory.

Hand. Hand is an old length measure, equal to 4 inches.

Hand Chaser. A hand chaser is a type of threading tool used either for cutting or chasing external or internal threads. The tool is supported upon a rest and is guided by the hand; it is used mainly on brass work, for slightly reducing the size of a thread that has been cut either by a die or threading tool. A hand chaser may also be used for truing up battered threads in repair work and for similar purposes.

Hand File. This type of file is parallel in thickness from the heel (end of file body next to tang or handle) to the middle, and is tapered, as to thickness, from the middle to the point, the latter being about one-half the thickness of the stock. The edges of the file are usually parallel throughout the entire length but are sometimes drawn in slightly at the point. The hand file is ordinarily preferred by machinists for finishing flat surfaces. The teeth are usually double-cut, bastard, although many files of this type have teeth of second-cut, smooth, or dead-smooth.

Hand Grinding. "Hand grinding" is the term applied to operations where the work to be ground, or the mechanism upon which the wheel is mounted, is held in the hands of the operator. It antedates all other grinding methods and is still used for a large variety of operations, ranging from the grinding of finest tools to the smoothing of large rough castings. The types of machines employed include bench and floor stands, swing frame, flexible shaft, portable electric and pneumatic, and the ordinary wet tool machines for sharpening lathe, planer and other machine shop tools.

Hand-Hole. In a steam boiler, a hand-hole is an opening that is large enough for the hand and arm to enter the boiler for washing out, for making slight repairs, or for inspection.

"Hand" of Milling Cutters. A cutter which rotates to the right (clockwise), as viewed from the spindle or rear side, is said

to be right-hand, and, inversely, a left-hand cutter is one that turns to the left (counter-clockwise) when viewed from the spindle of the machine.

Hand Reamer. A "hand" reamer is used by hand for producing holes that are to be smooth and true to size. The reamer consists of a cutting portion, a shank, and a square by which it is turned when in use. Between the cutting part and the shank, there is a short neck, the purpose of which is to provide clearance for the grinding wheel when grinding the cutting edges and the shank of the reamer.

Handsaw File. These files have the same section as a "three-square" type but differ in that the edges are given the proper bluntness to insure durability; the three-square files have comparatively sharp edges so that they are entirely unfit for filing saws. While the term "taper" is commonly used to denote a file which tapers in a lengthwise direction toward the point, custom has also established the term "taper" as a short name for the three-square handsaw file. One class of handsaw file is tapered to a small point and the teeth are single-cut, second-cut. These files are very extensively used for sharpening handsaws. Some saw files are double-cut, second-cut, these being preferred by some for filing fine-tooth saws.

Hand Screw Machine. Turret lathes of the screw-machine class are sometimes given names which indicate rather definitely the type of machine; for instance, the name *hand screw machine* is often applied to turret screw machines in general, in order to distinguish between the hand-operated type and the automatic type; or the term "hand screw machine" may indicate a design not equipped with an automatic feeding mechanism for the turret slide.

Hand Taps. As the name indicates, hand taps are intended primarily for use by hand, although at the present time regular (standard) hand taps are also used extensively in machines. They are a short tap with thread and shank approximately the same length, the latter having a square to accommodate a tap wrench or other driving mechanism. Hand taps are made in fractional sizes only.

Regular (standard) hand taps are furnished in "taper," "plug," or "bottoming" types the difference being in the number of threads chamfered which is, approximately, as follows: Bottoming taps are chamfered 1 to 1½ threads; plug taps, 2½ to 5 threads; and taper taps 7 to 9 threads.

Two- or Three-Fluted Hand Taps: These are regular (standard) hand taps in every way except that they have a less number

of flutes. Suitable for machine use in tapping tough stringy metal.

Spiral-Pointed Hand Taps: These are regular (standard) hand taps having a fewer number of flutes and wider lands and having the cutting face of the first few threads ground at an angle to force the chips ahead to prevent clogging in the flutes.

Serial Hand Taps: Regular (standard) hand taps in sets of three, the No. 1 being smaller than the No. 2 and the No. 2 being smaller than the No. 3 in pitch diameter, so that the work is distributed among three taps. Used for very tough metal where a full thread cannot be cut at one pass.

Hanger Bolt. A hanger bolt is one having a lag-screw thread at one end and a regular standard thread at the other end, used for attaching shaft hangers to wooden beams or posts.

Hardening Machine. A term that is sometimes applied to machines designed to prevent distortion when parts are quenched for hardening. See Quenching Apparatus.

Hardening Steel. The operation of hardening steel consists fundamentally of two steps. The first step is to heat the steel to some temperature above (usually at least 100 degrees F. above) its transformation point so that it becomes entirely austenitic in structure. The second step is to quench the steel at some rate faster than the critical rate (which depends on the carbon content, the amounts of alloying elements present other than carbon, and the grain size of the austenite) to produce a martensitic structure. The hardness of a martensitic steel depends upon its carbon content and ranges from about 460 Brinell at 0.20 per cent carbon to about 710 Brinell above 0.50 carbon. In comparison, ferrite has a hardness of about 90 Brinell, pearlite about 240 Brinell, and cementite around 550 Brinell.

Critical Points of Decalescence and Recalescence: The critical or transformation point at which pearlite is transformed into austenite as it is being heated is also called the *decalescence* point. If the temperature of the steel was observed as it passed through the decalescence point, it would be noted that it would continue to absorb heat without appreciably rising in temperature, although the immediate surroundings were hotter than the steel. Similarly, the critical or transformation point at which austenite is transformed back into pearlite upon cooling is called the *recalescence* point. When this point is reached, the steel will give out heat so that its temperature instead of continuing to fall, will momentarily increase.

The recalescence point is lower than the decalescence point by anywhere from 85 to 215 degrees F., and the lower of these points does not manifest itself unless the higher one has first

been fully passed. These critical points have a direct relation to the hardening of steel. Unless a temperature sufficient to reach the decalescence point is obtained, so that the pearlite is changed into austenite, no hardening action can take place; and unless the steel is cooled suddenly before it reaches the recalescence point, thus preventing the changing back again from austenite to pearlite, no hardening can take place. The critical points vary for different kinds of steel and must be determined by tests in each case. It is the variation in the critical points that makes it necessary to heat different steels to different temperatures when hardening.

Hardening Temperatures: The maximum temperature to which a steel is heated before quenching to harden it is called the hardening temperature. Hardening temperatures vary for different steels and different classes of service, although, in general, it may be said that the hardening temperature for any given steel is above the lower critical point of that steel. Just how far above this point the hardening temperature lies for any particular steel depends upon three factors: (1) the chemical composition of the steel; (2) the amount of excess ferrite (if the steel has less than 0.85 per cent carbon content) or the amount of excess cementite (if the steel has more than 0.85 per cent carbon content) that is to be dissolved in the austenite; and (3) the maximum grain size permitted, if desired.

The general range of full hardening temperatures for carbon steels is shown by the diagram. This range is merely indicative of general practice and is not intended to represent absolute hardening temperature limits. It can be seen that for steels of less than 0.85 per cent carbon content, the hardening range is above the upper critical point—that is, above the temperature at which all of the excess ferrite has been dissolved in the austenite. On the other hand, for steels of more than 0.85 per cent carbon content, the hardening range lies somewhat below the upper critical point. This indicates that in this hardening range some of the excess cementite still remains undissolved in the austenite. If steel of more than 0.85 per cent carbon content were heated above the upper critical point and then quenched, the resulting grain size would be excessively large.

At one time it was considered desirable to heat steel only to the minimum temperature at which it would fully harden, one of the reasons being to avoid grain growth that takes place at higher temperature. It is now realized that no such rule as this can be applied generally since there are factors other than hardness which must be taken into consideration. For example, in many cases toughness can be impaired by too low a temperature just as much as by too high a temperature. It is true, however, that too high hardening temperatures result in warpage,

distortion, increased scale, and decarburization.

Hardening Temperatures for Carbon Tool Steels: The best hardening temperatures for any given tool steel are dependent upon the type of tool and intended class of service. Wherever possible, the specific recommendations of the tool steel manufacturer should be followed. General recommendations for hardening temperatures of carbon tool steels based on carbon content are as follows: For steel of 0.65 to 0.80 per cent carbon content, 1450 to 1550 degrees F.; for steel of 0.80 to 0.95 per cent carbon content, 1410 to 1460 degrees F.; for steel of 0.95 to 1.10 per cent carbon content, 1390 to 1430 degrees F.; and for steels of 1.10 per cent and over carbon content, 1380 to 1420 degrees F. For a given hardening temperature range, the higher temperatures tend to produce deeper hardness penetration and increased compressional strength while the lower temperatures tend to result in shallower hardness penetration but increased resistance to splitting or bursting stresses.

Hard-Facing. Hard-surfacing or "hard-facing" consists in welding to parts subject to excessive wear, a facing, edge, or point of hard metal which is exceptionally resistant to abrasion. By this method, metal surfaces that normally wear away rapidly in service receive adequate protection from the added layer of wear-resistant alloy. Hard-facing materials are also being applied to numerous parts that may not have to resist abrasive wear at all, but that must be able to resist heat, erosion, corrosion, or a combination of these. Hard-faced valves are now regularly employed in many large power plants for handling high-pressure, high-temperature steam. Many oil refineries are also using hard-faced valves for handling hot sulphur-bearing oil and for other applications where corrosion and erosion are encountered.

In the automotive industry, hard-faced valve-seat inserts are used and hard-facing has been extended to the valves. Valves and seats so protected will last practically as long as the entire engine; moreover, they require a minimum of adjustment. Valve-stem ends are also being hard-faced. Many machine builders are now using hard-faced surfaces, edges, and points in the equipment that they build. To meet the various requirements of hardness, toughness, shock resistance, etc., many hard-facing alloys of widely different compositions have been developed. These may be divided into four broad groups:

Low-Alloy Steels: No sharp definition of composition. Alloying constituents usually less than 5 per cent, but may extend almost to 10 per cent. Not as wear-resistant as the other groups, but have some advantage in toughness and shock-resistance. Manganese, chromium, molybdenum, vanadium, and tungsten are

common alloying elements, generally with about 0.3 to 0.6 per cent of carbon.

High-Alloy Steels: Alloying elements in excess of 10 per cent. Almost invariably contain high-chromium for extra wear-resistance. Manganese, cobalt, tungsten, and nickel may also be present. Somewhat more expensive than the low-alloy steels but have markedly greater wear-resistance which may make for greater economy in the long run.

Non-Ferrous Alloys: Cobalt, chromium, and tungsten are usually the alloying elements. Highly resistant to wear, with a range of different grades having a spread in strength and toughness which makes them suitable for a large number of hard-facing applications. Because of non-ferrous composition, original hardness is practically unimpaired at elevated temperatures.

Tungsten Carbides: The so-called diamond substitutes, which are the hardest and most wear-resistant of all hard-facing materials. Some are almost pure fused tungsten carbides; others contain 90 to 95 per cent tungsten carbide, with the remainder usually cobalt, nickel, or iron. Generally furnished in the form of small castings, known as inserts, or as welding rods, in which the hard particles are packed in steel tubes. Because of their extreme refractoriness, these compounds are not melted or otherwise greatly affected by the oxy-acetylene flame. They are "wetted" by the molten metals and become fused in place—much as a lump of tinned steel might be soldered to a piece of copper. Thus they are held in place without difficulty.

Materials That Can Be Hard-Faced: All plain carbon and low-alloy steels can be processed by this method, provided the carbon content is not substantially in excess of 0.5 per cent. Steels having higher carbon and alloy contents require, under some circumstances, special heat-treatments subsequent to the surfacing operation, and a pre-heating of the part to be surfaced may even be required. Gray cast iron and alloy cast iron are readily hard-surfaced. On the other hand, brass, copper, or bronze cannot be hard-surfaced because of their relatively low melting points.

The selection of a suitable base material for hard-facing is important. For parts requiring considerable resistance to shock and impact, such as hot and cold trimming dies, S A E 3140 steel has proved to be a particularly ideal base material. This steel will not mushroom under impact, since it can be given its standard heat-treatment after hard-facing.

Application of Stellite: Stellite welding rod can be applied by either the oxy-acetylene or the electric arc process, although the former is always preferred, since dilution of the hard-facing deposit with iron from the base metal can be held to a minimum. Another factor to be considered in connection with the arc

method is that approximately 8 to 10 per cent of the electrode is lost through volatilization and spattering. Briefly, there are three important points to be borne in mind: (1) The surface to be hard-faced should be clean, free from dirt and scale; (2) an excess acetylene flame should be used; (3) the surface should be brought only to a sweating heat and not melted.

The aim in applying Stellite is to flow the alloy over the surface of the base metal when the latter is at sweating heat. If this is propely done, a strong junction is secured without any appreciable inter-alloying of the two metals. The exceptional properties of Stellite depend upon its non-ferrous composition of cobalt, chromium, and tungsten. Dilution with iron would reduce its ability to resist abrasion. An excess acetylene flame must be used in order to secure the proper sweating of the base metal. It is necessary to see that no particles of scale are covered during the process. If these simple precautions are taken, any welder can, with a little practice, produce a good hard-facing job.

If the electric arc is used, the polarity should be reversed, making the rod the positive electrode. In using the arc, it is impossible to avoid some inter-alloying of the two metals, but this should be kept to a minimum. A 1/4-inch Stellite rod requires 175 to 200 amperes, and a 5/16-inch rod, 225 to 250 amperes. In the majority of cases, hard-facing deposits range from 1/16 to 1/4 inch thick.

Hardie. The *hardie* is a form of chisel for use in conjunction with an anvil. It is made with a square shank to fit the hardie hole in the anvil, and is used for light cutting, such as trimming the ends of small forgings and cutting light stock. The piece to be severed is laid upon the chisel edge of the hardie and is struck with a hammer.

Hardness of Steel and Tensile Strength. There is a constant relationship between the ultimate tensile strength of steel and its hardness; hence the latter may be determined if the former is known, or vice versa. The following simple rules show the approximate relationship between tensile strength and hardness, as determined by both the Brinell and Rockwell tests.

Brinell hardness = tensile strength × 0.002 approximately

Rockwell hardness (C scale) = tensile strength × 0.0002 approximately

Example—Tensile strength of S A E nickel-chromium steel No. 3230 when hardened and drawn to 1100 degrees F. is 120,000 pounds per square inch. Determine the Brinell and the Rockwell hardness numbers.

Brinell $= 120{,}000 \times 0.002 = 240$; Rockwell $= 120{,}000 \times 0.0002 =$ C24

Example—The hardness of a molybdenum steel No. 4340 is 330 Brinell. Determine its approximate tensile strength.

$$\text{Tensile strength} = \frac{330}{0.002} = 165{,}000 \text{ pounds per square inch.}$$

Hardness Scale. See Mohs's Hardness Scale.

Hardness Testing. Brinell Hardness Test; Electromagnetic Hardness Testing; Jominy Hardenability Test; Keep's Test; Knoop Hardness Test; Pendulum Hardness Tester; Rockwell Hardness Test; Sclerometer; Scleroscope; Vickers Hardness Test.

Hard Solders. Hard solders, such as are used for silver soldering, and known as *silver solders,* are composed of silver, copper and zinc or brass; whereas hard solders which are used for brazing are alloys formed of copper and zinc. The hard solder used for brazing is commonly known as *spelter* or *spelter-solder.* The composition of silver solders varies considerably according to the nature of the work. A silver solder extensively used by jewelers contains 70 parts of silver and 30 parts of copper.

Hardware Balls. Hardware or C-grade steel balls are balls which may have a slightly defective surface and which are of poorer quality than the steel balls generally used in machine ball bearings.

Harmonic. A harmonic is any component of a periodic quantity which is an integral multiple of the fundamental frequency. For example, a component the frequency of which is twice the fundamental frequency is called the second harmonic.

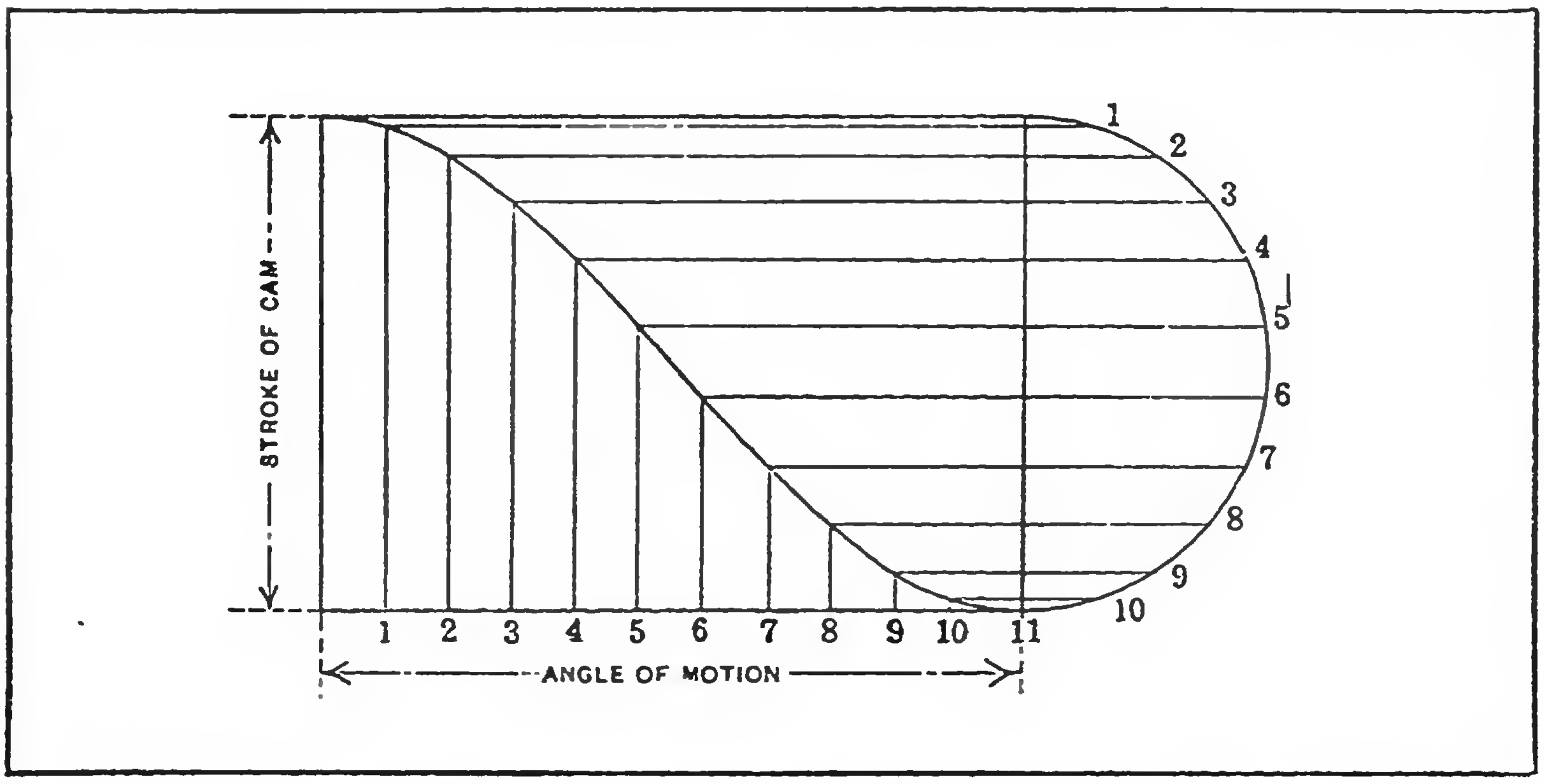
A harmonic, in electricity, is an alternating-current electromotive force wave of higher frequency than the fundamental, and superimposed on the same so as to distort it from a true sine-wave shape. It is caused by the slots, the shape of the pole pieces, and the pulsation of the armature reaction. The third and the fifth harmonics, i.e., with a frequency three and five times the fundamental, are generally the predominating ones in three-phase machines.

Harmonic Motion Curve. The crank or harmonic motion curve works much more easily than the uniform curve, and a cam laid out with this motion may be run at a high speed without much shock or noise. To draw a diagram of this curve, draw a semi-circle having a diameter equal to the stroke of the cam, and divide this semi-circle and the line representing the angle of

motion into the same number of equal parts. The intersection of lines drawn from these divisions will give points on the curve. The illustration shows the harmonic curve and the manner in which it is obtained.

Harvey Grip Thread. The characteristic feature of this thread is that one side inclines 44 degrees from a line at right angles to the axis, whereas the other side has an inclination of only 1 degree. This form of thread is sometimes used when there is considerable resistance or pressure in an axial direction and when it is desirable to reduce the radial or bursting pressure on the nut as much as possible. See Buttress Threads.

Harvey Process. In 1891, H. A. Harvey invented a process for making solid steel armor plates. The essential principle of the Harvey process is the subjection of the plates, while they are in contact with finely divided charcoal, to a high temperature for about two weeks. They are then allowed to cool slowly to a dull red heat, and sprayed with water. Plates made by this process have about twice the resisting power of wrought iron. In principle, this is simply a casehardening process applied to unusually large objects: the carbon from the charcoal penetrates the surface of the metal and converts it into high-carbon steel. The depth of the penetration and the amount of the carbon absorbed by the surface of the armor plate increases with the temperature and with the length of time allowed for the process.



Crank or Harmonic Motion Curve

Hastelloy B. Alloy composed of nickel, molybdenum and iron, having a tensile strength in the forged, rolled, and fully annealed state of 135,000 to 140,000 pounds per square inch, with an

elongation of 44 per cent in 2 inches. Is also unusually strong at high temperatures, and highly corrosion-resistant. Developed primarily for equipment handling hydrochloric acid in all concentrations and at temperatures up to and including the boiling point; also resists sulphuric, phosphoric, and acetic acids, as well as non-oxidizing acid chloride solutions. Suitable for agitator units, heating and cooling coils, pump parts, pickling tanks, valves, etc.

Haulage Rope. Wire ropes made from six strands of seven wires each are known as "haulage" rope, and also as "transmission" or "standing" rope. This type of rope is not very flexible, and is generally made with large wires, in order to enable it to resist a great deal of external wear. It is used when the abrasive action is great but when the rope is not required to bend over many sheaves and when the diameter of the sheaves is comparatively large. A greater factor of safety is required in haulage rope than in more flexible rope.

Haveg. A phenol-formaldehyde plastic with unusual acid-resisting properties. Can be used for temperatures up to 265 degrees F.; does not crack when cooled from this high temperature to the freezing point. Suitable in the metal-working industries for constructing or lining pickling tanks. Tanks up to 9 feet in diameter by 9 feet in height have been made from this material in a single piece, without seams or joints.

Header. A header is a large pipe into which one set of boilers is connected by suitable nozzles or tees, or similar large pipes from which a number of smaller ones lead to consuming points. Headers are often used for other purposes—for heaters or in refrigeration work. Headers are essentially branch pipes with many outlets, which are usually parallel. They are largely used for the tubes of water-tube boilers.

Heading Machine. A machine for cold-heading rivets, screw blanks, etc., is called a heading machine or cold-header.

Head or Pressure. The pressure against which a pump forces the water is usually expressed in "feet head." For example, a pump feeding a boiler against a pressure of 100 pounds per square inch is operating under a head of $100 \div 0.433 = 231$ feet; that is, each pound pressure per square inch against which the water is forced is equivalent to lifting a column of water 1 inch square and 2.31 feet high. From the above, it is evident that: Pressure per square inch in pounds $\div$ 0.433 = head in feet; and head in feet $\times$ 0.433 = pressure per square inch in pounds.

In determining the pressure head or total height to which the water must be raised, the distance must be taken from the sur-

face of the water in the reservoir from which it is drawn to the point of discharge. The same power is required to raise water by suction as to force it, and the height of the pump above the water does not enter separately into the calculation at all. This is made plain by a practical example. Assume that a pump is raising water by "suction" 18 feet, and discharging it at this elevation without forcing it at all, 'all the work being done on the suction side of the piston. When water is raised to this height by suction, the air pressure in the suction pipe is reduced to $14.7 - (18 \times 0.433) = 6.9$ pounds per square inch. This leaves an unbalanced pressure upon the other side of the piston equal to $14.7 - 6.9 = 7.8$ pounds per square inch. The effect is, therefore, the same as if the pump were forcing the water against this pressure with the water flowing into the cylinder by gravity. To illustrate, take a case where the water flows to the pump by gravity, and is raised to a height of 18 feet. Here the pressure per square inch against which the piston must work is $18 \times 0.433 = 7.8$ pounds, the same as in the preceding case. Hence, it is evident that the work done by the pump is the same whether the water is raised a given distance by suction or forced to the same height by the pressure of the piston.

Friction Head: In what has been said regarding the pressure head required for raising water to a given height, or forcing it against a pressure, as in boiler feeding, no reference has been made to the resistance due to the friction of the water against the sides of the pipes. In computing the required power for operating a pump, and the pipe sizes in a boiler plant where the distances are short, no account is taken of this, but when water is moved long distances through pipes, the friction must be taken into consideration. For convenience in making computations, tables have been prepared giving the frictional resistance for pipes of different diameters and different velocities of flow of water.

Headstock. That part of a lathe and of certain other machine tools, which contains the main spindle with its driving mechanism, is known as the headstock. Some designs of engine lathes have what is commonly referred to as a *friction head.* This is simply a headstock arranged with a friction clutch between the cone-pulley and the large faceplate gear. This clutch serves to connect either the cone-pulley and spindle for the direct drive, or the faceplate gear and spindle when the drive is through back gearing. The clutch is operated by a lever at the front of the headstock. This is a very convenient feature and makes it possible to change to the back-gear drive without stopping the lathe, and enables speed changes to be made much more quickly than with the ordinary design of headstock. Lathes which are com-

monly referred to by manufacturers as the *geared-head* type, have a headstock which contains a system of gearing so arranged that the drive may be transmitted through different combinations of gearing for varying the spindle speeds. There is either a direct-connected motor or, in case of a belt drive, a single belt pulley instead of a cone-pulley, and the gearing required for obtaining the necessary range of spindle speeds is entirely enclosed. The levers for controlling the clutches by means of which the speeds are varied are located in front of the headstock. The relative positions of the levers for obtaining a given speed are indicated by an index plate.

Heat and Heat Transfer. Since energy in the form of heat is transferred in three basically different ways, conduction, convection, and radiation, it is inconvenient to define heat in terms of the form adopted while in transition. A more satisfactory procedure is to identify heat as any transfer of energy which occurs whenever certain conditions are established. Thus, irrespective of which of the three forms of transfer is occurring, a necessary and sufficient condition for heat flow is the maintenance, or the transient existence, of a difference in temperature between the two thermally connected materials between which the energy transfer is taking place.

Common experience tells us that whenever a hot object is placed in a cool room the object undergoes a loss of temperature with respect to time and, since temperature is an indication of the quantity of kinetic internal energy in storage, it appears that stored energy must be flowing from the hot object to the cooler room; this energy transfer is defined as heat. When the situation is reversed and a cold object is introduced into a warm room the temperature of the object is observed to rise, hence internal kinetic energy is going into storage in the object; the flow of this energy from the room or surroundings to the object is likewise defined as heat. Thus, energy transfer as heat occurs because of a temperature difference within the thermal system.

Since any energy transfer which occurs because of a temperature difference is, by definition, heat, we must expect the term to include widely divergent methods of energy flow. Three such methods can be readily classified in terms of the different relationship, existing in each case, between the energy and the working substance (the material under consideration undergoing the energy transfer):

Radiation: When energy transfer takes place between two objects at different temperatures by means of a flow of massless particles, photons, which are not part of nor associated with the working substance, the transfer is said to be by radiation.

Radiant heat transmission is characterized by the complete independence of the energy quanta of any intermediate substance. Radiation, therefore, would readily occur through a perfect vacuum. In common experience the most vivid evidence of radiant transfer is that represented by the solar energy which passes through interstellar space (where conditions are infinitesimally close to those existing in a perfect vacuum) on its way to the earth's surface. Thus, radiation can occur without the presence of any "bridge" of working substance. As a corollary, radiation usually does not occur when a working substance is present, that is, radiation, in the wavelengths associated with ordinary thermal systems, does not take place through either a liquid or a solid. Through most gases radiation occurs as though the gas were not present, carbon dioxide being a marked exception and water vapor another exception.

Conduction: Whenever the molecules of a working substance, whether liquid, solid, or vapor, are restrained so that no appreciable relative translatory motion occurs among them, the kinetic energies of the various molecules will be largely due to vibration. If a temperature difference exists in the working substance, some adjacent molecules will necessarily be at different temperatures hence will possess different degrees of vibratory motion. In this case the molecule which is vibrating most rapidly will transfer some of its motion to the slower-moving molecule next to it, the one then undergoing a decrease in temperature and the other an increase. In this way, thermal energy will be transferred by the mechanism of conduction from the region of higher to the region of lower temperature. The process will continue spontaneously until the entire system has reached a uniform equilibrium temperature. If external conditions prevent attainment of a uniform temperature, as, for example, when one end of a copper rod is placed in a fire and the other end in an icebox, heat will continue to flow by conduction from the region of higher to the region of lower temperature.

In contrast to radiation, conduction only occurs when a working substance is present and when the molecules of that working substance retain practically fixed positions with respect to one another. Thus, conductive heat flow would always occur through solids, but would take place in liquids and vapors only if special conditions prevented or greatly reduced the normal translatory motion of the molecules within these materials.

Convection: All materials undergo some change in specific volume (hence in density) as a function of temperature. In solids, the restraining forces between molecules are sufficient to hold them in relatively fixed positions with respect to one another. This prevents any tendency of the molecules to move

so as to equalize the density throughout the solid. Thus, for example, a vertical copper rod may be cold at the top and warm near the bottom, but the heavier, colder, material will not be able to "sink" through the rod and displace the lighter, hotter, material.

With liquids, vapors, and gases the situation is markedly different and any difference in density immediately leads to downward flow of the heavier material and upward flow of the lighter. But since differences in density, at constant pressure, are always due to differences in temperature, it follows that for liquids, gases, and vapors there will always be mass flow associated with temperature gradient and a net transfer of internal kinetic energy from the region of higher to the region of lower temperature. Admittedly the "flow" in this case is of fluid and not of energy, the energy merely being carried by the fluid in stored form; however, since the net effect is a transfer of energy, and since it occurs because of and in the direction of a temperature gradient, this mechanism of transfer is grouped under the classification "heat" and referred to as convective heat transmission.

Convection is fundamentally a mixing process and any method of increasing the rate of mixing will correspondingly increase the rate of convective transfer. When mixing takes place solely through the effect of gravity on macroscopic fluid volumes of different density, the process is said to be one of *free convection.* If the mixing process is initiated or accelerated by mechanical means (as a pump, fan, or any type of stirring device) the process is defined as *forced convection.* Effectiveness of convection as a mechanism of heat transmission obviously depends on the difference of energy intensity as determined by temperature gradient and on the rate of mass transfer as influenced by pressure gradient throughout the fluid.

The three different mechanisms of heat transmission are characterized by three fundamentally different relationships between energy and mass. In radiant transfer the energy is transferred without any connection between the masses involved and the effect of any material present between the masses is to reduce or to eliminate entirely the radiant transmission. In conductive transfer the energy flows because of inter-molecular relationships in the working substance. The presence of mass is necessary for conductive transfer and the molecular arrangement must be such that there is no appreciable relative translatory motion, except that of vibration, among the molecules of the working substance. In convective transfer, the presence of mass is not only a requirement, but in addition there must be macroscopic transfer of the mass from the warmer to the cooler region and vice versa.

"Heat-Black" Finish. The so-called "heat-black" finish on brass, copper, or bronze is adapted for a large variety of work. The article to be treated should be free from grease, although a slight tarnish will not affect it. Two stock solutions are first made up. One is a solution of nitrate of copper in water and the other is a solution of nitrate of silver in water. The *nitrate of copper* solution is composed of water, 1 ounce and nitrate of copper, 1 ounce. The *nitrate of silver* solution contains water, 1 ounce and nitrate of silver, 1 ounce. The mixed solution for applying to the metal is made as follows: water, 3 parts; nitrate of copper solution, 2 parts; nitrate of silver solution, 1 part. The solution is kept in a glass or stoneware vessel for use.

The parts to be treated, freed from grease, are heated over a bright charcoal fire, or by means of a gas torch, under a hood, by the side of the tank containing the solution. The solution is kept in a china or stone basin of suitable proportions for the work to be treated; such basin is covered with a wooden cover, and kept under the hood connected with the chimney drawing out the fumes generated, when the parts are dipped in the solution. After the parts have been dipped, they are allowed to drain over the basin for a few seconds, and then heated again until the green froth is burnt and black. If the charcoal fire is used, care must be taken that the wet parts do not touch the coals, as this would cause discolored spots at every point of contact. It will not be detrimental to have the parts laying on the fire when they are dry and green all over. The brushing is made over a tank full of water by means of a wet brush to prevent inhaling the irritating dust. The parts are allowed to dry and afterwards may be finished or they may be smeared with oil, dried in sawdust, and brushed again, or else polished with black lead.

One or two coatings of the solution on the surface of the article is usually enough; it dries almost immediately leaving a green froth. The temperature is not sufficiently high to draw the temper of hard brass, but it will usually melt soft solder. When the entire surface has changed to a uniform black color, allow the article to cool and then brush off the fluffy material on the surface of the metal with a stiff-bristled brush. The color will now change to a brownish-black that is quite pleasing for many purposes.

When the smut has been brushed off from the surface of the article, it is immersed in a cold liver of sulphur solution for 5 minutes. The solution is made by dissolving 2 ounces of liver of sulphur in 1 gallon of water. The article is immersed in it, allowed to remain about 5 minutes and then, without rinsing, is again heated until the surface is uniformly black. The surface is now brushed again with the bristle brush when it will be found that the color is a dead black and quite uniform. If the article is

lacquered with a flat lacquer or waxed, as may be desired, the final appearance of the surface will be found satisfactory. This is one of the most satisfactory black finishes known, as it is dead black, is readily applied, and very durable.

Heat Coloring. Heat coloring is a method of producing a variety of colors on iron and steel articles by heating them until the desired shade is obtained, and then permitting them to cool off. One method is to heat a flat piece of iron and steel of sufficient size to retain the heat for some time and place the piece to be colored on the hot surface. When the desired color appears, the piece to be colored is plunged into an oil bath. Hot sand or a Bunsen burner may also be used for heat coloring.

Heat Density. The number of British thermal units (B.T.U.) of heat that are in a cubic foot of space under various conditions will be given approximately, assuming 0 degrees F. as a base. On a hot summer day, with the thermometer registering 110 degrees, there is only 1.8 B.T.U. to the cubic foot.

The gasoline blast torch is generally assumed to have a very hot flame, but in the hottest part of that flame the heat density is only 10 B.T.U. per cubic foot. Hydrogen gas, with its enormous heat value, might be expected to have a larger number of units, but in the hottest part of a hydrogen flame burned in the air the B.T.U. per cubic foot are just about 10.1; it has a heat density 1 per cent better than the gasoline flame in air. Carbon burned in air shows a density of 12.3 B.T.U. per cubic foot. Acetylene gas burned in air produces a heat density of 13.1 B.T.U. per cubic foot. Eliminate nitrogen and burn acetylene in oxygen and there are 24 B.T.U. in every cubic foot of the intense flame. Burn hydrogen in oxygen and there are 20 B.T.U. to the cubic foot.

Ordinary steam just as it boils off water into the atmosphere contains 44 B.T.U. to the cubic foot. The oxy-acetylene flame takes a poor second place when compared with steam under these conditions. Superheated steam at 240 pounds per square inch and 300 degrees of superheat, contains over 500 B.T.U. per cubic foot. Strange as it may seem, saturated high-pressure steam at 235 pounds per square inch contains over 650 B.T.U. per cubic foot, and for carrying heat is superior in this respect to superheated steam. A cake of ice at 32 degrees will deliver 937 B.T.U. per cubic foot when cooled down to zero. Boiling water holds over 12,000 B.T.U. per cubic foot.

Melted sulphur, at 800 degrees F., has a heat density about twice that of boiling water, or over 22,000 B.T.U. to the cubic foot. Melted aluminum, at 1214 degrees F., almost doubles this with nearly 43,000 B.T.U. per cubic foot. Melted glass, at 2377 de-

grees F., has nearly 75,000 B.T.U. in every cubic foot. Platinum, at 3300 degrees F., makes a big jump with its 182,200 B.T.U. per cubic foot. But common melted iron, at 2700 degrees F., leaves platinum away behind with 207,000 B.T.U. per cubic foot. However, they are all surpassed if a cubic foot of carbon is heated almost to its vaporizing temperature, say to 7000 degrees F., as a heat density of 700,000 B.T.U. per cubic foot is then obtained. It is impossible for a person to look at this heated carbon or stand near it, and probably it represents the greatest heat density known. It is found in every arc lamp.

Heat Equivalent of Work. It has been found by experiment that there is a definite relation between heat and work, in the ratio of one British thermal unit to 778 foot-pounds of work. The number 778 is commonly called the *heat equivalent of work* or the *mechanical equivalent of heat.*

A horsepower-hour equals $33{,}000 \times 60 = 1{,}980{,}000$ foot-pounds. The changing of one pound of water at 212 degrees F. into steam at that temperature, will require about 966 British thermal units, or $966 \times 778 = 751{,}600$ foot-pounds nearly. This being the case, it is evident that the number of pounds of water evaporated at 212 degrees F., which represent one horsepower-hour, equals $1{,}980{,}000 \div 751{,}600 = 2.64$ pounds of water.

Heat Insulating Materials. See Insulation, Heat; also Pipe Coverings.

Heat of Evaporation. The heat of evaporation is the total amount of heat required for the changing of water of a given temperature into steam of the same temperature.

Heat Pump. The "heat pump" is an apparatus working on a reversed heat-engine cycle, the object of which is to economize heat in evaporating processes, such as the concentration or the distillation of liquids. In the heat-pump process the vapor from the evaporator is taken to a compressor, in which its pressure, and hence also its temperature, are raised to such a degree that the compressed vapor may serve as the heating medium in the evaporator. It is returned to the heating element of the evaporator accordingly, where it is used for the evaporation of a further amount of liquid. While in certain circumstances a small quantity of live steam may have to be supplied, in general the only energy required in order to carry on the process is that necessary to drive the compressor. The efficiency of the process from the thermal or energy point of view may therefore be measured by comparing the evaporative effect produced with the power expended in driving the compressor. This power may be derived from fuel consumed in the power unit or station from which the

compressor is driven, or, of course, from any other source of power, such as water power, and involve no expenditure of fuel at all. Also the compressor may be driven directly by the prime mover or the drive may be indirect, the transmission being effected electrically. The compressor may also take the form of a jet pump supplied from an external source with steam which mixes with the vapor from the evaporator, and is delivered with it to the heating element. The variations of the process are numerous, but all are characterized by the fact that the vapor produced is compressed and returned to the evaporator as the heating medium.

Heat-Resisting Alloy. See Calite.

Heat, Specific. See Specific Heat.

Heat-Treatment. This term as applied to steel means, according to the S.A.E. definition, an operation or a combination of operations involving the heating and cooling of a metal or an alloy which is in the solid state, for the purpose of obtaining certain desirable conditions or properties. Heating and cooling for the sole purpose of mechanical working is not classified as heat-treatment. Generally speaking, the heat-treatment of steel, includes hardening and tempering of high-carbon steels, casehard-

Table 1. Hardening Carbon Tool Steel

Per cent Carbon	Hardening Temperature, Degrees F.	Quenching Medium	Temperature of Quenching Medium, Degrees F.
0.65 to 0.80	1550 to 1450	Water	70
0.81 to 0.95	1460 to 1410	Water	70
0.96 to 1.10	1390 to 1430	Water	70
1.11 to 1.25	1380 to 1420	Water	70

Table 2. Tempering Carbon Tool Steel

Results Desired	Tempering Medium	Temperature, Degrees F.
Relieving strains	Oil	350 to 375
Relieving strains and reducing brittleness	Oil	400 to 500
Relieving strains and toughening	Oil	500 to 600

ening of low-carbon steels, and annealing of steel. Refer to following sections and also to process or equipment, as, for example, Annealing; Barium-chloride Heating Baths; Casehardening Steel; Carburizing by Rotary Method; Cyanide Hardening; Hardening Steel; Local Hardening; Pack Hardening; Quenching Baths; Tempering.

Heat-Treatment of Carbon Steel. The operations required for heat-treating or hardening plain carbon tool steel are heating, quenching, and tempering. The heating should be done uniformly and Table 1 gives temperatures which may be used as a general guide. From this temperature the steel is quenched in water, but should not be permitted to cool down below the temperature of boiling water (212 degrees F.). The steel may be tempered by being reheated immediately in oil, a salt bath ($NaNO_3$), or in a furnace. Tempering temperatures are given in Table 2.

The quenching temperatures given are at the lowest temperature ranges consistent with high quality tools; deviations are not recommended, but may be necessary in unusual cases. Water is the common quenching medium, and by varying its temperature and manner of application for the abstraction of heat, almost any degree of variation of structural conditions of the tool steel can be obtained. There are, however, special cases where oil may be a more suitable quenching medium; judgment and experience are the only guides in cases of this kind. The recommended practice for the heat-treatment of tool steel applies to tools for general purposes only. For specific applications, where special requirements seem to be necessary, deviation from the recommended practice must be left to the judgment of the individual heat-treater or metallurgist.

Heat-Treatment of High-Speed Steel. The following directions apply in the heat-treatment of 18 per cent tungsten high-speed steel:

Annealing: Heat slowly and uniformly to a temperature of 1600 degrees F., and hold at that temperature to obtain uniformity of internal condition and grain. Cool in a furnace or in infusorial earth, mica, lime, or any medium that will permit slow, uniform cooling. Cooling in air should not be permitted, since air cooling from the annealing temperature is likely to result in partial hardening of the tool.

Preheating for Hardening: Heat slowly and uniformly to 1600 to 1700 degrees F. in a furnace of sufficient size. The steel should be "soaked" well in preheating to permit even heat penetration. This preheating should be done gradually especially if there are thin and thick sections.

Heating for Quenching: Transfer the preheated steel to a high-

temperature furnace which is maintained at a temperature of from 2250 to 2400 degrees F., as a general rule. In order to obtain the most satisfactory "red hardness" conditions, the steel should be brought rapidly to the higher temperature; but in many cases the character of the cutting edges of certain form tools, such as milling cutters, threading tools, etc., makes it inadvisable to use the higher temperatures because of the danger of destroying the delicate edges through blistering, pitting, etc. It is therefore usual to employ the higher temperatures for such tools as rough lathe tools, while the finer class of tools is hardened at the lower temperatures. High-speed steel tools should not be held at the high heat longer than necessary, since holding at the high hardening temperatures causes excessive grain growth, with subsequent brittleness of the hardened tools. Tools that cannot be ground after hardening are often heated in a barium chloride or some similar salt bath.

Quenching High-Speed Steel: Quench the steel in oil which is kept cool by a cold water jacket around the tank or in a salt bath. The quenching tank should be placed close to the hardening furnace, so that the distance from the fire to the oil will be as short as possible. When the tool has cooled below 300 but not below 200 degrees F., transfer it to the tempering medium. High-speed steel tools, especially if of intricate design or requiring exceptional toughness. may be quenched in a bath of molten salt or lead having a temperature of from 950 to 1200 degrees F. The tool should attain the temperature of the bath before removal, and this usually requires immersion from 15 to 30 minutes. After removal, the tool is allowed to cool in still air to between 200 and 300 degrees F. before placing in the tempering bath.

Tempering or Drawing High-Speed Steel: In tempering, the steel should be allowed to "soak" well until it has attained the full temperature of the furnace and an even heat penetration throughout. Next it should be removed to a dry place that is free from air drafts, and allowed to cool off gradually. Do not quench, as this tends to produce strains in the finished tool that may develop into cracks later under the friction heat of operation. A salt bath is recommended for tempering high-speed steel, although furnaces may also be used. The bath or furnace temperature should be increased gradually, say, from 300 to 400 degrees up to the tempering temperature which may range from 1050 to 1150 degrees F. for high-speed steel or from 1200 to 1300 degrees F. for steels containing cobalt. The temperatures given apply only to lathe, planer, and similar heavy-duty tools that frequently heat up to the point of visible redness while in operation. In general, a tool should be drawn as near as possible to the highest temperature it will attain in actual operation—if above 850 de-

grees. If it is to be subjected to shocks in operation, a higher draw is necessary. Milling cutters, forming tools, and similar tools for lighter duty, may be drawn at temperatures as low as 850 degrees. Drawing below 850 degrees, however, is not practical, as it leaves the tool too brittle.

Heat-Treatment, Solution and Precipitation Methods. These methods of heat-treatment may be applied to certain nonferrous alloys such as wrought aluminum and also to some of the magnesium or Dowmetal alloys.

Wrought Aluminum Alloys: The wrought alloys of aluminum may be divided into two classes depending upon the manner in which their harder tempers are produced. One class comprises the alloys in which strain-hardening, by definite amounts of cold work following the last annealing operation, produces the varying degrees of strength and hardness. The alloys in the other class depend primarily upon heat-treatment processes to develop their higher mechanical properties.

While there is a wide range of tensile properties in both classes of alloys, the highest combinations of strength and ductility available in the widest range of products are to be found in the heat-treated alloys. In the aluminum alloys which respond to heat treatment, the alloying constituents which give the increased strength and hardness are substances which are more soluble in solid aluminum at high temperatures than at low temperatures.

Solution Heat-treatment: The first step in heat treatment, frequently called the "solution heat treatment," consists in heating the alloy to a high temperature, below the melting point, to put as much as possible of the alloying constituent into solid solution, then quenching to retain this condition. When in solid solution, the alloying constituent is so finely dispersed that it is not visible with the microscope, even at high magnification. In effect, the alloying constituent has been dissolved in the aluminum and dispersed as completely as when sugar is dissolved in water.

Precipitation Heat-treatment: After quenching, the alloy undergoes an aging process which, if carried out at elevated temperatures, is called a "precipitation heat treatment," because during this stage some of the alloying constituent which is held in solid solution precipitates from the solid solution in the form of extremely fine particles. This precipitation may occur spontaneously at room temperature, as is the case in the so-called "natural aging" of certain alloys, or it may require a "precipitation heat treatment" or "artificial aging" at about 300°F., in the case of certain other alloys.

Heat-treatment of Dowmetal Alloys: Dowmetal castings may be used as cast or in a heat-treated condition. Heat-treatment is not required for general use. However, when increased tensile

strength, ductility and toughness are required, without change of yield strength or hardness, castings are "solution heat-treated." This solution heat-treatment is performed in specially designed ovens at temperatures varying from 630 to 785 degrees F., depending upon the alloy, and is followed by air-cooling. Castings so treated are in the best condition for shock resistance. If castings require high yield strength but are not subject to shock, they are solution heat-treated and aged. This aging or "precipitation" is done at about 350 degrees F.

Heat Units. The unit of heat measurement used in English-speaking countries is the British thermal unit (B.T.U.), which is the quantity of heat required to raise the temperature of one pound of pure water one degree F. The French thermal unit, or kilogram-calorie, is the quantity of heat required to raise the temperature of one kilogram of pure water one degree C. One kilogram-calorie equals 3.968 British thermal units, and it also equals 1000 gram-calories. The number of foot-pounds of mechanical energy equivalent to one British thermal unit is called the "mechanical equivalent of heat," and equals 778 foot-pounds. One foot-pound equals 0.001285 heat unit.

Hectograph Composition. This is a compound used as an oil-proof cement, consisting of two parts of good glue or gelatin, one part of glycerin, and seven parts of water, the preparation being applied warm. On cooling it will stiffen quickly.

Hefner Standard. The Hefner standard or unit is the standard of intensity of light as adopted in Germany. The standard intensity of a Hefner is equal to 0.9 international candle, the latter having, since 1909, been established as the national standard for light intensity in Great Britain, France, and the United States. The Hefner standard is the light produced by a wick lamp burning amyl acetate of definitely specific chemical and physical properties, the standard height of flame being 40 millimeters (about 1⅝ inch). The Hefner standard as a unit for the intensity of light is objected to on account of its low intensity, its reddish color, and its sensitiveness to variations in the height of the flame. The element of uncertainty is estimated to almost always exceed 2 per cent.

Hele-Shaw Clutch. This is a clutch devised by Prof. Hele-Shaw. Its principal feature is that power is transmitted through the friction between grooved disks. A number of these disks are placed in the clutch, each disk having a V-groove which fits into the V-groove of the next disk. Every other disk is connected to an outside drum, and the alternating disks, to the shaft to which power is to be transmitted. It has been found that V-shaped

disks transmit considerably more power and permit of a more even "pick-up" than clutches with flat disks.

Helical. See Helix Angle; also Spiral and Helix.

Helical Gears. Gears which have a cylindrical pitch surface and teeth which coincide with helical curves on the surface of the pitch cylinder, are known as *helical gears.* Helical gears are also known as "spiral gears," although the teeth are helicoidal like a screw thread and not of spiral form. Various terms are used to designate helical gears. For instance, when helical gearing is used to connect parallel shafts, the term "twisted spur gear" is sometimes used, because the gearing in this case serves the same general purpose as ordinary straight-tooth spur gearing. This relates to the use of single-helical and not the double-helical or "herringbone" gearing. When helical gearing is used to connect shafts located at an angle, the term "helical" or "spiral" is commonly applied, both terms being extensively used. Both of these general classes of gearing have helicoidal teeth, and the principles underlying the methods of cutting them are similar, but the tooth action (when the gears are running together) is quite different, and so also are the functions of the gearing. Thus, when helical gears are used to connect parallel shafts, the object is to secure a smoother action than can be obtained with ordinary spur gears. On the other hand, helical gearing is frequently used as a convenient means of transmitting motion between shafts that are located at an angle and not in the same plane. When parallel shafts are connected by gearing having both right- and left-hand helical teeth, the terms "herringbone" or "double-helical" gears are commonly used, the former being more common.

Helical Gears, Cutting. Helical gearing is usually cut by some generating method, although milling machines are sometimes used, especially when such gears are not required in quantity. Large helical gears, particularly in the herringbone form, may also be cut on planers of the form-copying type and by the end-milling process. The most common generating method employed is that of hobbing. Gear hobbing machines are very efficient for cutting helical gears, and are widely used for this class of work as well as for spur gears. The general method for cutting helical gears by hobbing is practically the same as cutting spur gears, after the machine is properly geared and adjusted.

Shaping or planing processes of cutting helical gears are used in many shops. The cutter used on a Fellows helical gear shaper resembles a helical gear and has a rotary movement in unison with the gear blank being cut, the principle of operation being similar to that of the shaper for spur gears.

Helical Gears for Angular Drives. Helical gearing for driving shafts which are not intersecting and not parallel is generally considered a rather treacherous type to use, when the amount of power is relatively high. In most installations, the power transmitted is much less than the maximum capacity of the gearing, and whenever the amount of power is likely to be anywhere near the maximum, it is preferable to use worm-gearing, assuming that the angle between the shafts is 90 degrees. If worm-gearing is used, the worm should have as many threads as are required to give the desired velocity ratio. Helical gears that have caused trouble due to abrasion resulting from the small contact area and highly localized pressure, have often been replaced by worm-gearing with satisfactory results. Whenever there is any doubt about the power-transmitting capacity of helical gearing, it is not advisable to rely upon calculations, but to determine this capacity by an actual test under actual running conditions, as regards speed, lubrication, and load.

Helical Gears for Parallel Shafts. Helical gears for parallel shaft drives have several inherent advantages as compared with the spur type. First, the action is distributed over more than one tooth, and all phases of tooth engagement, such as sliding and rolling contact, occur simultaneously, which tends to equalize wear and preserve the correct tooth shape. The load is transferred gradually and uniformly as successive teeth come into engagement, and the bending action resulting from the tooth load is less than for a spur gear, because the line of contact extends diagonally across the meshing teeth; the tooth load of a helical gear, however, is higher because of the angular position of the teeth, and the normal tooth section is, of course, smaller than that of a spur gear of the same circular pitch.

Three Classes of Problems: Helical gear designing problems for parallel-shaft drives may be divided into three very general classes. In considering these three classes or cases, reference to diametral pitch will be made by way of illustration, but the same principle would apply if the gear were designed on the basis of circular pitch.

Case 1: When a special helical gear hob or cutter is used having some standard diametral pitch in the plane of rotation: Such a hob or cutter is special in that the tooth thickness is reduced an amount depending upon the helix angle, thus making the circular pitch of the gear in the plane of rotation equivalent to a standard diametral pitch.

Case 2: When a standard spur-gear hob is used because a special helical gear hob is not available: In this case the diametral pitch of the hob represents the normal diametral pitch of the gear and the diametral pitch in the plane of rotation will be an

odd fractional pitch unless the pitch in the plane of rotation is also made standard, as explained in the next paragraph.

Case 3: When a standard spur-gear hob or cutter is used and a special helix angle is selected to make the diametral pitch in the plane of rotation standard as when spur gears are to be replaced by herringbone or single-helical gears without changing the center distances between the shafts or the ratio.

Replacing Spur Gears with Helical Gears: When spur gears on some existing machine are to be replaced either by single-helical or double-helical (herringbone) gears and both center distance and ratio must be retained, it may be possible to cut the helical or herringbone gear with a hob or cutter of standard pitch by making the helix angle special.

RULE: Select a hob or cutter having a diametral pitch equivalent to a slightly smaller tooth than that of the spur gearing to be replaced. Divide diametral pitch of spur gearing by diametral pitch of hob selected, thus obtaining cosine of helix angle required.

EXAMPLE 1: A machine has shafts connected by spur gears having 30 and 90 teeth, respectively, of 6 diametral pitch. Determine pitch of hob and helix angle of helical or herringbone gears to replace spur gears. If a spur-gear hob of 7 diametral pitch is used,

$$\text{Cos special helix angle} = \frac{6}{7} = 0.85714$$

Hence helix angle equals 31 degrees, and with this angle the diametral pitch in the plane of rotation will be 6, like the spur gears which are to be replaced.

EXAMPLE 2: The spur gears, Example 1, are to be replaced by herringbone gears and a hob of 4 module (metric) is available. Determine helix angle.

The equivalent diametral pitch equals $25.4 \div 4 = 6.35$; hence

$$\text{Cos special helix angle} = \frac{6}{6.35} = 0.94488$$

The equivalent angle is 19° 7′ and the diametral pitch in the plane of rotation is 6, as required.

Helical Gears, Helix Angles and End Thrust. The selection of an angle for parallel shaft drives may depend to some extent upon the allowable end thrust, as, for example, in cases where a certain amount of end thrust would be tolerated in order to use a larger angle and obtain smoother tooth action. In many helical-gear transmissions for parallel-shaft drives, it is customary to use fairly small helix angles. Often an angle as small as 7 degrees is used; 12 degrees is favored by some designers; and

either 23 or 30 degrees is customarily used for double-helical or herringbone gears.

In automotive practice, angles up to 45 degrees and even larger are used. The angles of the helical gears used in automotive transmissions were increased in order to obtain quieter gearing. However, tests have shown that it is not necessary to use as steep helix angles as have been employed to obtain the best results. In theory, the steeper the angle, the quieter should be the gears, because of the tooth overlap; but this is true only of perfect gears, which cannot be produced, especially in regular production work. Generally speaking, the helix angles of transmission second-speed gears in use at the present time range from 25 to 45 degrees. Many designers at the present time prefer angles between 30 and 40 degrees.

Tests were made to determine, if possible, just what angle should be used to obtain the greatest degree of quietness for the second-speed gears in a transmission. Sets of gears, beginning with spur gears and ending with 45-degree helical gears, were cut and lapped as nearly perfect as possible. All the gears were cut with the same hob and finished with the same lap, after which they were thoroughly inspected. The pinion and drive gear were in a 2 to 1 ratio, the helix varied by 5-degree increments from spur gear (0 degree) to 45 degrees. An adjustable-center-distance case was used. The general results of the tests were that the noise decreased until a 20-degree angle was reached, but, from that point on, there was no noticeable improvement.

End Thrust: In order to determine the end thrust of helical gearing as applied to parallel-shaft drives, first calculate the tangential load on the gear teeth. If the amount of power to be transmitted is 7 horsepower and the pitch-line velocity 200 feet per minute, the tangential load will equal $33{,}000 \times 7 \div 200 =$ 1155 pounds. The axial or end thrust may now be determined approximately by multiplying the tangential load by the tangent of the tooth angle. Thus, in this instance, the thrust $= 1155 \times \tan$ 15 degrees $=$ about 310 pounds. The end thrust obtained by this calculation will be somewhat greater than the actual end thrust, because frictional losses in the shaft bearings, etc., have not been taken into account, although a test on a helical gear set, with a motor drive, showed that the actual thrust of the 7½-degree helical gears tested, was not much below the theoretical values.

The ratio between peripheral tooth pressure and resultant thrust was determined by measurements taken while the gearing was in operation under various loads. The tangential tooth pressure was determined in the usual way from observed revolutions per minute and wattage. Corrections of horsepower were made from an efficiency chart of the motor. The thrust was measured

by applying a graduated spring balance against the end of the motor shaft with sufficient pressure to balance the thrust and move the shaft away from the face of the bearing. As there was over ¼ inch end play between the bearings, it was easy to tell when the thrust surfaces were separated. This test showed conclusively that the thrust developed by helical gearing was practically proportional to the tangent of the helical angle.

Helical Gear Terms and Dimensions. The diagram illustrates a helical gear (see Fig. 1). The teeth have a helix or tooth angle a. This angle is measured from the axis, as the diagram shows, and it represents the inclination at the pitch diameter.

The sum of the helix or tooth angles of a pair of mating helical gears is equal to the shaft angle or angle between the shaft axes.

Pitch Diameter: The number of teeth and the pitch diameter are terms which are identically the same as those used for spur gearing.

To find the pitch diameter of a helical gear, divide the number of teeth by the product of the normal diametral pitch and the cosine of the tooth angle.

Diametral Pitch: Practically all helical gears are made to the diametral pitch rather than the circular pitch system. The regular diametral pitch of a helical gear will be found, the same as for a spur gear, by dividing the number of teeth by the pitch diameter in inches. It is not necessary to know what this is, however, since it does not enter into the calculations, and since the cutter used has to be for a somewhat finer diametral pitch. This is shown by the diagram. The normal diametral pitch, or diametral pitch of the cutter used, is reckoned from measurements taken along the pitch cylinder at right angles to the length of the tooth. P' represents the regular circular pitch, while P'_n represents the normal circular pitch. The normal diametral pitch may be found by dividing 3.1416 by P'_n. It may also be found by dividing the number of teeth by the product of the pitch diameter D and the cosine of helix angle a. This is the pitch of the cutter to be used.

Shaft Angle: The shaft angle of a pair of helical or spiral gears is the angle made by the two center lines or axes of the gears, as taken in a view perpendicular to both axes. The diagram, Fig. 2, shows three sets of helical gears taken in the plane which shows the shaft angles. At the left is the ordinary case in which the shafts are át right angles with each other, so that the angle (γ) is 90 degrees. In the second case, γ is less than 90 degrees, and in the example shown at the right, it is more. It should be noted in the last two cases that the position of the shaft axes is identical, but that the two shaft angles are located on opposite sides of axis A. In order to know on which side of the

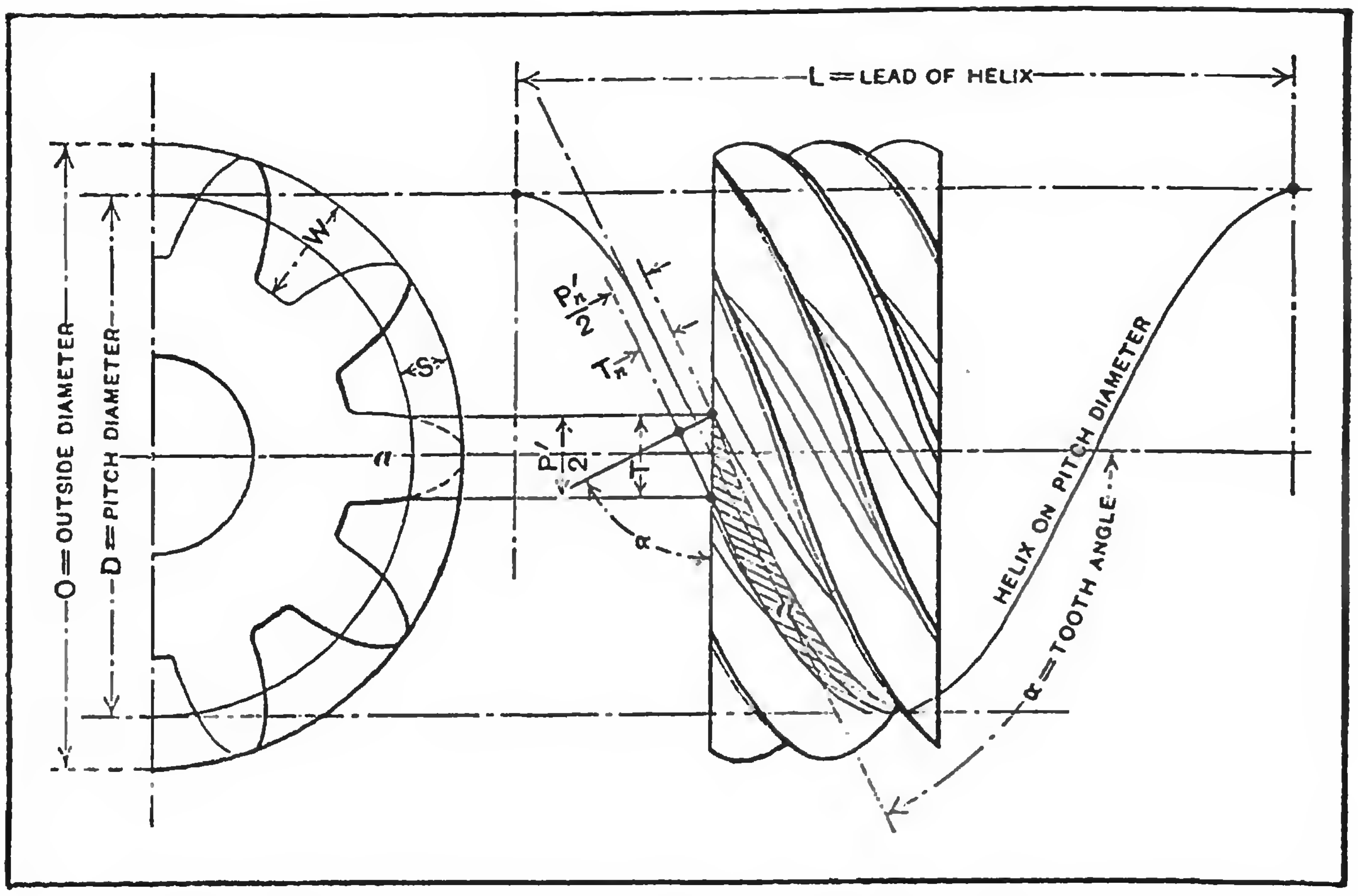


Fig. 1. Diagram of Helical Gear Illustrating Terms used in the Calculations

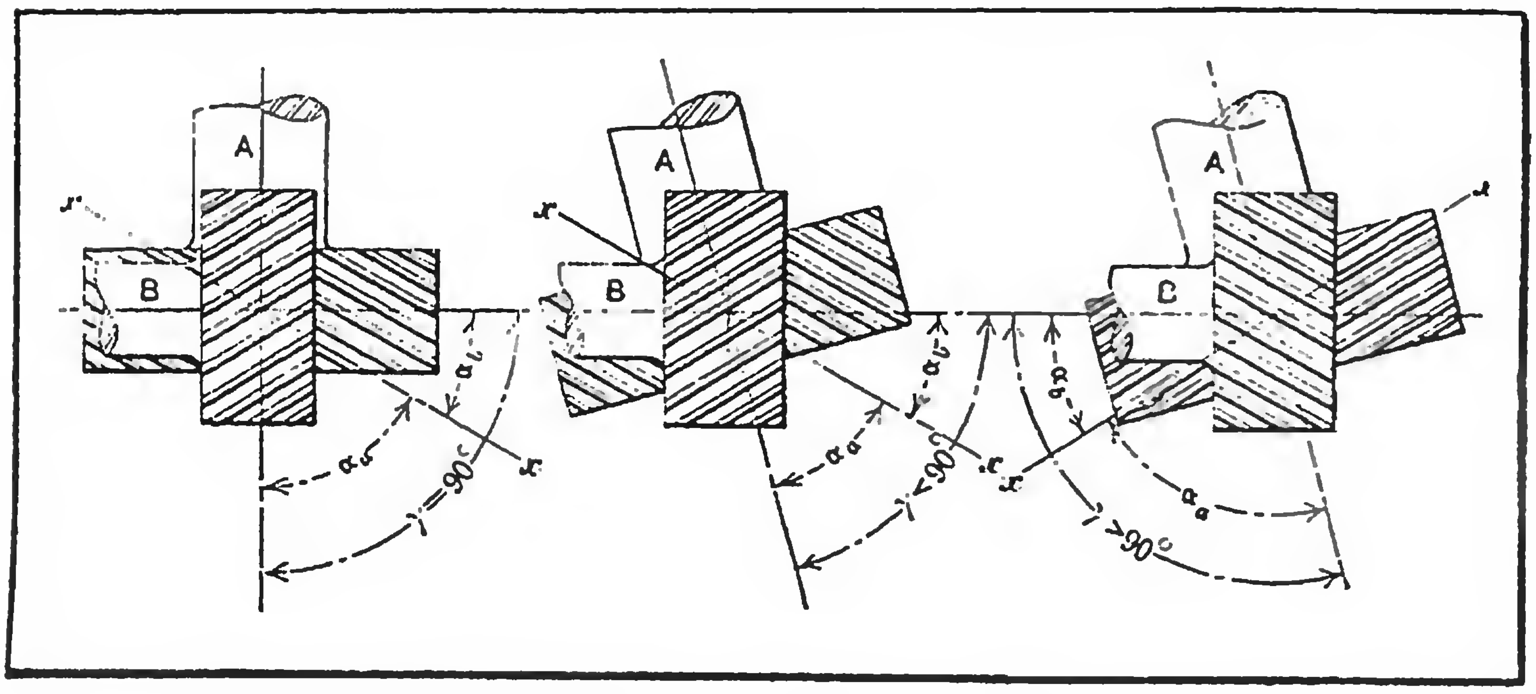


Fig. 2. Helical Gears with Different Shaft Angles

center line to take the center angle in cases like those shown, the position of the teeth of the gears in contact must be considered. The center angle is taken at the side which includes the line x–x, passing lengthwise of the teeth of the gears at the point of contact with each other. Since the teeth are laid out differently in the two cases, the angles are different. The case shown in the center is the more usual of the two, the other being very rare.

Helium. Helium is one of the lightest of the gases, although not so light as hydrogen, its specific gravity, compared with air as a unit, being 0.138. Helium is present in small quantities in

the atmosphere, and also in many minerals. It is contained almost universally in the gases in the water of thermal springs. It does not enter into a chemical combination with any other chemical element, but is always mechanically mixed or contained in the substance in which it is found. Helium becomes liquid at a temperature of only a few degrees above the absolute zero, and becomes solid at a temperature only two degrees below that at which it liquefies, these temperatures being around —267 degrees C. (—449 degrees F.). According to laboratory experiments at the University of Leyden, Holland, it appears that at absolute zero a pressure of about 16 atmospheres would be required to solidify helium. The actual solidification took place at a temperature about 2.2 degrees C. above absolute zero at a pressure of 50 atmospheres, and at 4.2 degrees C. above absolute zero at a pressure of 140 atmospheres. Solid helium forms a homogeneous transparent mass which differs to an extremely small extent from the appearance of liquid helium.

Helix. A helix is a curve in three dimensions; that is, it is not a curve situated in one plane. Examples of this curve are found in the helical spring, the helical or spiral gear, and the ordinary screw thread. In a sharp V screw thread, for example, the line forming the top of the thread forms a helix. The distance between the various convolutions of the helix, measured parallel to its axis, is known as its *lead*. Helices are often, although incorrectly, referred to as *spirals*. A spiral, however, is a curve situated in one plane and is exemplified by an ordinary watch spring having consecutive layers or convolutions extending outward.

Helix Angle. If the base of a right-angle triangle equals the lead of a screw thread and if the altitude equals the pitch circumference of the screw, then the angle between the hypotenuse and altitude of the triangle equals the helix angle of that screw thread at the pitch line; hence, the tangent of the helix angle equals the lead of the thread divided by the pitch circumference (circumference at one-half the thread depth). It is evident from the foregoing that the helix angle of a screw thread is measured from a plane perpendicular to the screw axis and it is usually known as the *lead angle*. This angle ordinarily is based upon the pitch diameter. If the helix angle at the top of a screw thread were required, the circumference at the outside diameter would be taken instead of the pitch circumference.

The helix angle of a helical (spiral) gear is measured from the axis. Thus if the lead (axial distance that a tooth would advance if it made one complete turn) of a helical gear equals the base of a right-angle triangle and if the pitch circumference of the gear

equals the altitude, then the angle between the hypotenuse and the base equals the helix angle; hence, the tangent of this helix angle equals the pitch circumference of the gear divided by the lead of the helix.

Helve Hammers. The power hammer commonly known as a *helve* hammer, is so named because the upper hammer die is attached to the end of a wooden helve. The hammer of a typical design is driven by a belt operating on a pulley and on the shaft which carries this pulley there is an eccentric which, by means of a suitable strap and connecting-rod, operates a lever or arm which, in turn, actuates the hammer helve; motion is imparted to the helve through rubber cushions which impart "snap" and elasticity to the blow. The wooden helve is hung upon hardened steel centers and may be adjusted to accommodate variations either in the thickness of the die or of the stock that is to be forged. The hammer is controlled by a foot-treadle which extends around the side and front of the hammer base. Helve hammers are made in several different designs which differ either in regard to the method of imparting motion to the helve or in the arrangement of the hammer die. Hammers of the helve class are especially adapted for comparatively light forging operations which require a succession of rapid blows, and they are extensively used for drawing out stock and, in some cases, special dies are employed for producing duplicate forgings of uniform shape and size.

Hematite Ore. Hematite ore, also frequently known as "red hematite," is an iron oxide of the composition Fe_2O_3, containing about 70 per cent of iron. Most of the iron ores mined in the United States belong to this class. The color of hematite varies from a bluish gray to a deep red, but it always gives a red streak on a porcelain plate. The hardness of hematite varies from 5.5 to 6.5 on the Mohs scale. The specific gravity varies from 4.2 to 5.3. Hematite is an anhydrous oxide containing no water in combination after having been heated to a temperature of 212 degrees F. See Iron in Iron Ore; also Magnetite.

Hemp Rope. The fiber of the hemp plant is used for making hemp rope. Hemp rope is not so strong as Manila rope of the same size. A hemp rope, if dry and untarred, will break from its own weight, at a length of about 2800 feet. If wet and tarred, it will break from its own weight at about 2000 feet. Sometimes, when the depths at which ropes are used are very great, they are given approximately the form of a body of uniform strength, by making them of separate pieces, the diameters of which diminish toward the lower end. In this way, the stresses in the fibers due to the rope's own weight can be considerably decreased.

Henry. The unit of inductance is called the *henry*, which is the inductance of a coil in which a current varying at the rate of one ampere per second will induce one volt. The one volt induced does not include the electromotive force necessary to overcome the resistance of the circuit. As this unit is too large for practical purposes, the *millihenry* (one thousandth of a henry) is the unit used in rating coils and electromagnets.

Heptagon. Any plane figure or surface bounded by seven straight lines is called a *heptagon.* If all of the sides are of equal length and the angles between the sides are equal, the figure is called a *regular* heptagon.

Hermaphrodite Caliper. A caliper provided with one straight pointed leg similar to that of a divider, and one leg with a bent end similar to that of an ordinary machinist's inside caliper is known as a hermaphrodite caliper. Calipers of this type are used in laying off distances from the edge of a piece of work and for locating the center of round work.

Herringbone Gears. Helical gears are often used for parallel-shaft drives because of the smooth continuous action. Single helical gears, or a right-hand gear on one shaft meshing with a left-hand gear on the other shaft, may result in excessive end thrust. End thrust may be avoided by placing on each shaft two helical gears side by side, having teeth cut in opposite directions. This type of gearing has been termed "herringbone" gearing. Herringbone gears may be formed of two half sections or of one solid piece. When there are two sections these may be cut separately, the same as two single-helical gears, and afterward bolted together so that the teeth of each section are either in alignment or staggered, as may be required. If herringbone gears are made of one solid piece, the right- and left-hand teeth may also be directly opposite or be offset an amount equal to one-half the circular pitch. Solid gears have a central clearance space between the right- and left-hand tooth sections when necessary to provide room for the cutter or hob, the amount of clearance required varying for different methods of cutting; the method may be such that the clearance space is eliminated entirely, the teeth extending across the gear without a groove at the center.

With herringbone gearing the bending stress on the teeth does not fluctuate from maximum to minimum, as in straight gears, but remains always near the mean value. This feature is of especial importance in rolling-mill driving and work of a similar nature. Herringbone gears are especially applicable for high velocities and ratios in connection with turbine reduction gearing or for installations requiring a minimum of vibration and noise. Accurate and well-made herringbone gears are often operated at

pitch-line velocities of from 3000 to 5000 feet per minute in connection with steam turbine reduction gearing, and the ratios may be 10 to 1 or higher for some installations.

Double helical or herringbone gears may be produced either by hobbing, planing (using either a gear shaper or planer) or milling. In hobbing gears of this type, an ordinary machine designed for cutting spur and helical gears may be used, or the work may be done on a special machine intended particularly for herringbone gears. If the planing process is employed, the teeth may be formed by a generating method, or a machine of the templet or form-copying type may be used.

Wuest Herringbone Gears: The teeth of the Wuest gears are so designed that those on the right- and left-hand sides of the gears are stepped half a space apart and do not meet at a common apex at the center of the face, as in the usual type of herringbone gear. The stepped form will wear more evenly under extreme loads than the ordinary type.

Hexavalent. This term is used to indicate that an atom of one element will combine with six atoms of another element. It is also known as sexivalent.

High Brass. What is known as "high brass" is especially suitable for cold rolling and drawing; it contains from 30 to 40 per cent of zinc, the remainder being copper. If there is over 0.1 per cent of lead, the ductility of the brass is decreased and for this reason sheet brass intended for drawing purposes should be as free from lead as possible.

High-Cycle Portable Tools. The term "high-cycle portable tools" is a trade designation for portable electric drills, grinders, sanders, polishers, nut-setters, etc., operated by a 180-cycle, three-phase, alternating current. As the available electrical power is generally either direct current or 60-cycle alternating current, the desired 180-cycle current is obtained from these sources by a motor-generator or a frequency converter. The main purpose of the development of high-cycle tools was to utilize the simplicity of the three-phase induction motor, with its indestructible rotating element, and to eliminate commutators and brushes, which are a source of considerable maintenance expense in universal motors. With the customary 60-cycle power supply of 60 cycles per second, the speed of the rotating element is limited to 60 revolutions per second, or 3600 revolutions per minute, which is changed to desired speeds for drilling or other operations by suitable gearing. With this low rotating-element speed, it was not possible to obtain the desired light weight of portable tools, combined with the degree of robustness and reserve power required,

and, consequently, the number of cycles was increased to three times that of the customary 60, or 180 cycles, giving a speed of the rotating element of 10,800 R.P.M., which is comparable with universal tool speeds.

High-Energy-Rate Forming. See Explosive Forming and Dynapak Process.

High-Frequency Induction Motors. Induction motors designed to operate at a speed greater than 3600 revolutions per minute (the maximum for squirrel-cage and wound-rotor motors with two poles, operating at 60 cycles) are called high-frequency motors because their operation is based on utilizing a high-frequency power supply. They are used in portable drills and woodworking machinery where small compact units of comparatively high horsepower are desired.

These motors are of the same construction as the standard squirrel-cage motors and their speeds range from 3600 to 18,000 revolutions per minute. Higher speeds are feasible if required commercially.

According to the National Electrical Manufacturers Association, the standard frequencies for these motors as used in portable hand tool applications is 180 cycles at 110 and 220 volts, and for motors as used in the woodworking industry or for general-purpose applications is 60 cycles and 120 cycles at 220 volts. At any other frequency the voltage will be in proportion to the frequency. The ratings of these motors are based on a continuous duty with a temperature rise of 40 deg. C.

Probably the majority of motors used in the machine tool industry are of the two-, four-, six-, or eight-pole type. The synchronous speed of an alternating-current motor is obtained by dividing the number of alternations per minute by the number of poles. For example, consider a two-pole motor operating on a 60-cycle circuit. Sixty cycles is equivalent to 7200 alternations per minute, and dividing this number by 2, the motor speed is found to be 3600 revolutions per minute. Since a motor cannot have less than two poles, 3600 revolutions per minute is the maximum speed that can be obtained on a 60-cycle source of supply. In order to obtain the higher speeds, it is necessary to increase the frequency or the number of cycles per second.

High-Speed Steel. The expression "high-speed steel" is derived from the fact that such steel is capable of cutting metal at a much higher rate of speed than ordinary carbon tool steels. The reason why high-speed steel can be used at higher speeds is that it has a special property known as "red hardness," or, in other words, this steel is able to retain its hardness even when

heated to a dull red; hence, when cutting at a high rate of speed, the steel, although it becomes heated to a degree which would make an ordinary tool steel useless, retains its cutting qualities. A high-speed steel is not necessarily one conforming to any given analysis but it is some kind of alloy steel. Most high-speed steels contain tungsten as the chief alloying element, but other elements, such as molybdenum, confer the red-hardness characteristic. A high-speed steel should continue to cut when the point of the tool becomes heated to a dull red temperature because of the red-hardness characteristic conferred upon it by tungsten, molybdenum or other alloys. The reason why high-speed steels in general can be heated considerably as the result of high cutting speeds and excessive friction is that some element (or combination of elements), such, for example, as tungsten, so changes the characteristics of the steel that the increase of temperature does not affect it, the same as with ordinary carbon steel.

While high-speed steel is valuable for metal-cutting tools because it will retain a cutting edge even at high temperatures, it is also used for many purposes where temperature is not a factor. This is true, for example, in the case of blanking dies, broaches, certain types of shear blades, etc. High-speed steel in the hardened condition has from five to eight times the wear resistance of a 1 per cent hardened carbon tool steel at ordinary room temperature.

High-Speed Steel Compositions. There are many different compositions for high-speed steels but the 18-4-1 steels, which contain 18 per cent tungsten, 4 per cent chromium, and 1 per cent vanadium, may be classed as the standard tool steels. This type is a very satisfactory general-purpose steel, as it can be easily forged, is relatively insensitive to variations in heat-treatment, and possesses considerable physical strength in addition to a high red-hardness. A steel of this analysis is used for most of the high-speed steel tools that are bought in a completed condition, such as drills, taps, and milling cutters. It is of particular value in that it is applicable to practically all machine shop operations.

The exact composition of these 18-4-1 tungsten steels varies somewhat. For example, the tungsten content may range from 17 to 21, the chromium from 3 to 4½, and the vanadium from 0.7 to 1½. High-speed steels of this general type are easier to harden than some of the other compositions, and they have proved very satisfactory for cutting various materials under normal conditions. The 18-4-1 steel is not only used extensively for forged lathe and planer tools, but for milling cutters, drills, reamers, taps, threading dies, punches, and sheet metal dies, etc.

The 14-4-2 Type: Another general class of tungsten high-speed steel is known as the 14-4-2 type. This is sometimes preferred

for heavy roughing cuts, but is not used as much today as formerly. Because of the lower tungsten content of 14 per cent, this steel is more sensitive to heat-treatment. The carbon content of the various classes of tungsten high-speed steels ranges from about 0.60 to 0.80 per cent. The usual carbon content is from 0.67 to 0.72, as this range gives the best combination of hardness, toughness, and cutting capacity. For a given tungsten and chromium content, the hardness and toughness varies in direct proportion to the carbon content.

Some turning tools are made from an 18-4-2 or "double-vanadium" type of high-speed steel. When applied to broaching, the 18-4-2 steel has proved superior to the 18-4-1 type.

Cobalt Steels: The high-cobalt or cobalt-tungsten steel is adapted to heavy roughing cuts. These cobalt steels are similar to the 18-4-1 tungsten steel with a certain amount of cobalt added. The high-cobalt tungsten steels contain usually from 7.5 to 12 per cent of cobalt. Tools made of this steel should not be forced to their maximum cutting capacity until the temperature has been raised by the cutting action. With the possible exception of small tools, high-cobalt steel should not be forged because it is more difficult to forge than the high-tungsten steel. As cobalt steels are more expensive than ordinary high-speed steel, it is common practice to weld or braze cobalt-steel tips to a cheaper grade of steel which is used for the shank.

Low-cobalt Steel: A low-cobalt high-speed steel has proved very satisfactory for finishing tools requiring tough hard edges. The cobalt type is superior to high-tungsten steel in withstanding relatively high temperatures and maintaining a sharp cutting edge when taking long finishing cuts. This is one reason why cobalt steel is specially adapted for tools used on automatic screw machines or wherever tool replacement involves some difficulty and long tool life is particularly important. A low-cobalt steel may contain from 4½ to 5 per cent of cobalt, 17 to 18 per cent tungsten, and 0.90 to 1.10 per cent vanadium.

Steels for Drills: Manufacturers of twist drills generally use practically the same analysis of high-speed steel. This analysis is approximately as follows: Carbon, 0.70; tungsten, 18; chromium, 4; and vanadium, 1 per cent. Steels with somewhat over 0.70 per cent carbon are generally used for small drills, while slightly less than 0.70 per cent carbon is used for the larger sizes. The 14 per cent tungsten high-speed steel is no longer used for drills. High-speed steel containing no tungsten, but instead approximately 7 per cent of molybdenum, has given very good results.

Cobalt high-speed steel drills find wide application in drilling hard metals which are beyond the capacity of ordinary high-speed

drills. In resisting the action of abrasion, the cobalt high-speed steel drills, with their higher carbon and alloy content, are superior to those made from ordinary high-speed steel, but they cannot be compared with tungsten-carbide tipped tools. The addition of cobalt to high-speed steel increases the "red hardness." In other words, cobalt high-speed steel drills can be subjected to higher cutting temperatures without destroying the edges.

High-Speed Steel, Super. The term "super high-speed steel" is applied to high-cobalt steels which are especially adapted to heavy-duty roughing operations. See Cobalt Steels under High-speed Steel Compositions.

High-Speed Steel, Tungstenless. See Cobaltcrom Steel.

Hindley Worm Gearing. Worm gearing of the Hindley type is generally supposed to have been originated by Henry Hindley, a noted clockmaker in York, England. There is no record of the year in which the Hindley worm gear was first made, but it was used in a dividing engine and described in a paper presented to the Royal Society by John Smeaton in 1785. In 1741 Smeaton had been shown a dividing engine containing this gearing. Hindley was also the inventor of the Hindley dividing engine, which was one of the first devices for accurately dividing a circle into a given number of equal parts.

Hindley worm-gearing or "globoid" gearing differs from ordinary worm-gearing in that the worm is curved in a lengthwise direction to fit the worm-gear, instead of being cylindrical. The idea is to so shape the worm that it will make contact throughout its length with the worm-gear, instead of engaging the gear along the mid-section only. Although perfect surface contact over all the teeth in mesh is not obtained, the contact is doubtless of a superior nature in well-constructed Hindley gearing. The exact nature and extent of the contact, however, is uncertain, owing to the fact that the theoretical contact does not agree with the results actually obtained by commercial manufacturing methods, which alter to some extent the theoretical form.

Hobbing Die Impressions. This method is designated as hobbing or hubbing, because a "hob" or "hub" is used, which is in the form of a punch and has a shape corresponding to the impression required in the die. See Hub Method of Die-sinking.

Hobbing Process. Gear teeth cut by the hobbing process are given the required shape or curvature by a generating action resulting from the rotation of the gear blank relative to a cutter of the hob form. Gear-hobbing machines are commonly applied to the cutting of spur, helical, and worm gearing, and hobbing is the most rapid method of cutting gears by a generating process.

In the practical application of the generating principle to gear-hobbing machines, the hob used has cutting teeth of the same cross-sectional shape as teeth of a rack of corresponding pitch, except for minor variations such, for example, as increasing the length of the hob teeth to provide for clearance at the bottom of the tooth spaces. As the hob teeth lie along a helical path (like a screw thread) the hob is set at an angle to align the teeth on the cutting side with the axis of the gear blank. When the hob is inclined an amount depending upon the helix angle of its teeth, the latter, on the cutting side, represent a rack.

When a hobbing machine is in operation, the gear blank and hob revolve together, the ratio depending upon the number of teeth in the gear and the number of threads on the hob—that is, whether the hob has a single or a multiple thread. This rotation of the hob causes successive teeth to occupy positions corresponding to the teeth of a rack, assuming that the latter were in mesh with the revolving gear and moving tangentially. In conjunction with the rotary movement of the hob, the slide on which it is carried is given a feeding movement parallel to the axis of the gear blank. As this feeding movement continues across the gear blank (or blanks when several are cut together) all of the gear teeth are completely formed; thus hobbing is a continuous operation, since the teeth around the entire circumference of the gear are finished together (instead of one tooth being cut at a time) and ordinarily by one passage of the hob.

Hob "End Angle." The angle at which the hob-spindle or swivel slide is set depends upon the lead of the hob thread and its diameter, since the object of inclining the hob is to bring the teeth on the cutting side into alignment with the axis of the gear blank. This angle is equal to the helix angle of the hob thread at the pitch-line, measured from a plane perpendicular to the hob axis, and is often called the "end angle." To avoid the necessity of making calculations, this angle is usually stamped on the hob. If the angle is not known, its tangent may be determined simply by dividing the lead of the hob thread by the pitch circumference.

Hob Flutes. If a hob is to be used in a gear-hobbing machine in which the hob and blank are positively geared together, the number of flutes may be comparatively small as compared with a hob that is to be used for hobbing worm-gears in a milling machine. A rule that agrees well with present practice is as follows: *To find the number of flutes in a hob, multiply the diameter of the hob by three, and divide by twice the circular pitch.* This rule gives approximate results on hobs for general purposes. In addition, the following considerations must be taken into account.

Some authorities on worm gearing state that the number of flutes in a hob should in no case be an exact multiple of the number of threads. Their reason for this rule is that the hob so gashed will produce a much smoother tooth and one nearer correct in shape, because no tooth in the hob passes the same tooth in the gear twice in succession, so that any imperfections in the shape of the individual hob teeth are counteracted by one another. According to another authority, the circumferential distance from flute to flute should not be equal to or equally divisible by the circular pitch, for the same reason as stated regarding the former rule. From the foregoing statements, it is seen that to obtain a rule that would be at once simple and yet take all conditions into consideration, would be difficult.

It is important that the number of flutes or gashes in hobs bear a certain relation to the number of threads in the hob and the number of teeth in the worm-wheel to be hobbed. Avoid having a common factor between the number of threads in the hob and the number of flutes; that is, if the worm is double-threaded, the number of gashes should be, say, 7 or 9, rather than 8. If it is triple-threaded, the number of gashes should be 7 or 11, rather than 6 or 9. The second requirement is to avoid having a common factor between the number of threads in the hob and the number of teeth in the worm-wheel. For example, if the number of teeth in the wheel is 28, it would be best to have the hob triple-threaded, as 3 is not a factor of 28. Again, if there were to be 36 threads in the worm-gear, it would be preferable to have 5 threads in the hob. It is desirable that hobs should be fluted at right angles to the direction of the thread. Sometimes, however, it is necessary to modify this requirement to a slight degree, because the hobs cannot be relieved unless the number of teeth in one revolution, along the thread helix, is such that the relieving attachment can be properly geared to suit it.

Hob Method of Die-Sinking. See Hub Method of Die-sinking.

Hobs, Multiple-Threaded. In cutting spur gears by the hobbing process, double- or even triple-threaded hobs are sometimes used instead of a single-threaded hob. A multiple-threaded hob will reduce the actual cutting time in direct proportion to the number of threads, as compared with a single-threaded hob of equal size, having the same speed and feed. A single-threaded hob, however, generates more accurate teeth, and it is the type commonly used. The reason that a hob having a double or triple thread reduces the cutting time in proportion to the number of threads will be evident by considering a specific example.

Assume that the gear to be hobbed has forty teeth, the hob feed per gear revolution is 0.1 inch, the total hob travel 2 inches,

and the hob speed 100 revolutions per minute. In using a single-threaded hob, the gear will revolve 20 times while the teeth are being cut, since $2 \div 0.1 = 20$; hence, the hob makes $20 \times 40 = 800$ revolutions while traveling 2 inches, and as the hob speed is 100 revolutions per minute, the actual cutting time equals $800 \div 100 = 8$ minutes.

Assume now that the same gear is to be cut with a double-threaded hob. If the feed is still 0.1 inch per gear revolution, 20 gear revolutions will be required for a total hob travel of 2 inches as before. The hob, however, makes 20 revolutions to one of the gear, instead of 40, as with the single-threaded hob. Since the double-threaded hob also rotates 100 revolutions per minute, the gear will have a speed of $100 \div 20 = 5$ revolutions per minute, instead of $100 \div 40 = 2\frac{1}{2}$ revolutions per minute, as for single-threaded hob; consequently, if the double-threaded hob feed is 1/10 inch per gear revolution, it moves $1/10 \times 5 = 5/10$ inch per minute, and it travels the required 2 inches in $2 \div 0.5 = 4$ minutes. This time, as will be seen, is one-half that required for a single-threaded hob, because the gear blank rotates at twice the speed when using a double-threaded hob.

If a similar comparison were made between a single-threaded and a triple-threaded hob, it would be found that the latter would require only one-third the cutting time needed for a single-threaded hob. The triple-threaded form is sometimes used for cast-iron gears which do not need to be very accurate. When multiple-threaded hobs are used for steel gears, ordinarily the double-threaded form is employed.

Hobs, Spline Shafts. The usual method of determining the form of the hob for straight-sided spline shafts is to roll the particular spline shaft as a gear, and thus develop the form of its corresponding basic rack. This is done on the drawing board, with the spline shaft suitably enlarged. The first problem to be solved is the position or size of the pitch circle for the spline. If it is too large, a troublesome fillet will be produced at the bottom of the spline. If it is too small, the top of the face of the spline will be rounded or beveled off.

When the splines are of involute form, the hob teeth have straight sides inclined to the desired "pressure angle" which, according to the American Standard, is 30 degrees. These hobs for involute splines are, of course, easier to make than hobs for the straight parallel-sided splines. The latter may be designed by the mathematical method which follows:

Establishing Hob Curvature Mathematically: When a calculating machine is available, the forms for the cutting edges of these hobs may be established analytically, to any degree of accuracy desired, in much less time than is required to obtain the same

results, to a lesser degree of accuracy, by a geometrical lay-out.

The following method and calculations for determining the form of the teeth of hobs for spline shafts is from Earle Buckingham, Professor of Mechanical Engineering, Massachusetts Institute of Technology.

Referring to Fig. 1:

A = half thickness of spline;
R = pitch radius of spline;
y = ordinate of line of action and hob profile;
X = abscissa of line of action;
x = abscissa of hob profile; and
E = angle of rotation (chosen arbitrarily).

Then,

$$\text{Cos } B = \frac{A}{R};\ D = B - E$$

$$y = \cos D\ (R \cos D - A)$$

$$X = \sin D\ (R \cos D - A)$$

$$x = R \text{ arc } E - X$$

As an example, take the S A E 1½-inch, ten-spline shaft. Use the outside radius as the pitch radius. This gives the following values:

$$A = 0.115;\ R = 0.750$$

Then,

$$\text{Cos } B = \frac{0.115}{0.750} = 0.15333 \text{ and}$$

$$B = 81 \text{ degrees, } 10 \text{ minutes, } 48 \text{ seconds}$$

Select successive values of E varying by 3 degrees. The calculations are shown in the accompanying table. The coordinates x and y of the hob tooth profile may be plotted to any enlarged scale desired, say 100 times the size. A curve may then be drawn through these points. From this graph, the series of coordinates needed in the shop to make the form tool can be readily measured. In Fig. 2 is shown an enlarged graph of this profile.

Hob Tooth Thickness at Pitch Line: The thickness of the hob tooth at the pitch line would be determined as follows:

N = number of splines;
R = pitch radius of spline shaft;
A = half thickness of spline; and
T = thickness of hob tooth at pitch line.

$$T = \frac{2\pi R}{N} - 2A$$

In the foregoing example, $N = 10$; $R = 0.75$; and $A = 0.115$. Then,

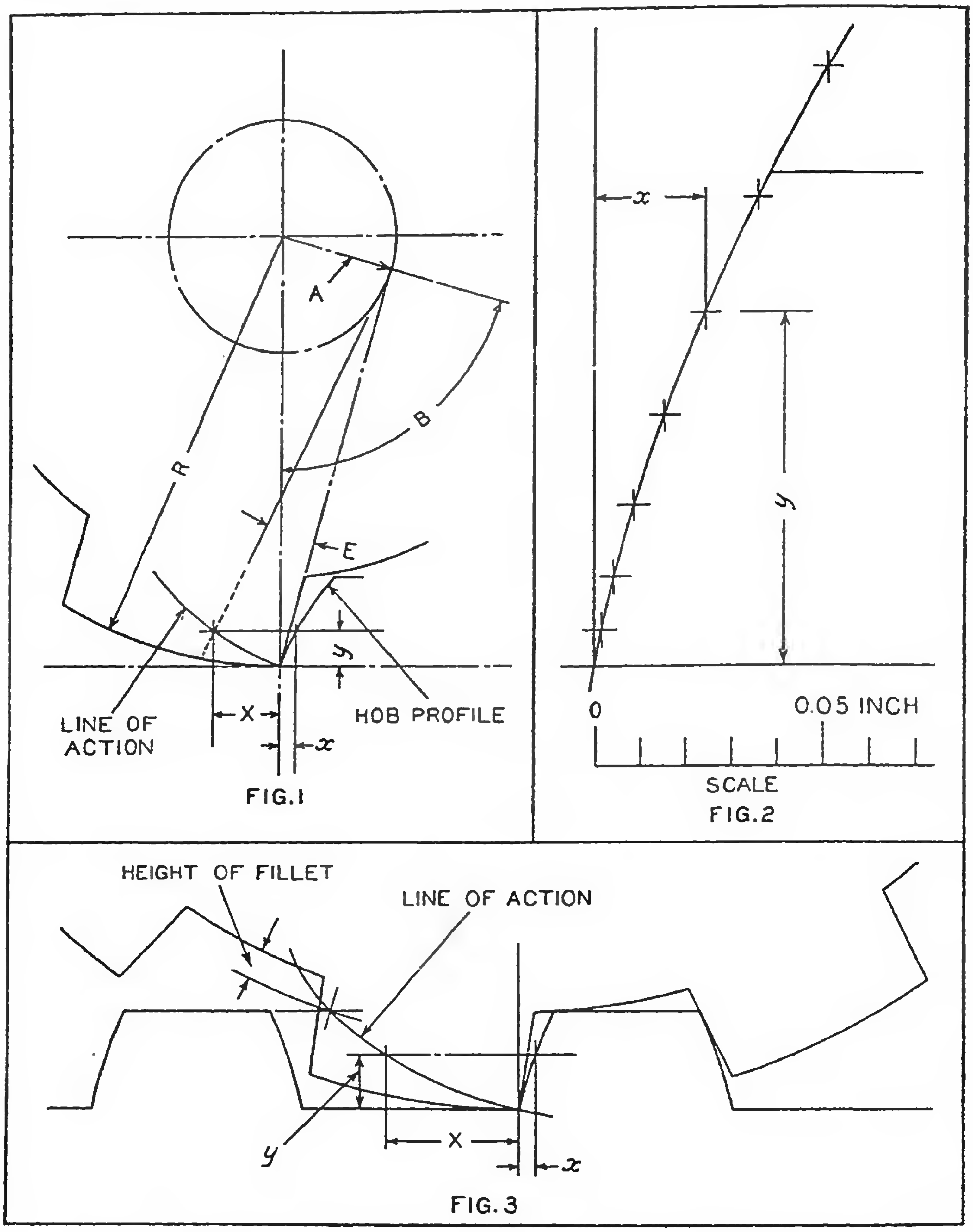
$$T = \frac{6.2832 \times 0.75}{10} - 0.23 = 0.2412$$

Calculations for Hob Tooth Form for S A E 1 1/2-Inch Ten-Spline Shaft

E	3°	6°	9°	12°
D	78° 10′ 48″	75° 10′ 48″	72° 10′ 48″	69° 10′ 48″
Cos D	0.20484	0.25550	0.30603	0.35548
Sin D	0.97879	0.96681	0.95200	0.93468
R cos D	0.15363	0.19163	0.22952	0.26661
R cos $D - A$	0.03863	0.07663	0.11452	0.15161
y	0.00791	0.01958	0.03505	0.05389
X	0.03781	0.07408	0.10902	0.14171
Arc E	0.05236	0.10472	0.15708	0.20944
R arc E	0.03927	0.07854	0.11781	0.15708
x	0.00146	0.00446	0.00879	0.01537
E	15°	18°	21°	24°
D	66° 10′ 48″	63° 10′ 48″	60° 10′ 48″	57° 10′ 48″
Cos D	0.40386	0.45119	0.49728	0.54200
Sin D	0.91482	0.89243	0.86759	0.84038
R cos D	0.30290	0.33839	0.37296	0.40650
R cos $D - A$	0.18790	0.22339	0.25796	0.29150
y	0.07589	0.10079	0.12828	0.15799
X	0.17189	0.19936	0.22380	0.24497
Arc E	0.26180	0.31416	0.36652	0.41888
R arc E	0.19635	0.23562	0.27489	0.31416
x	0.02446	0.03626	0.05109	0.06919

This hob tooth profile, line of action, and a section of the spline shaft are shown in Fig. 3. The height of the fillet at the bottom of the spline can be determined, as indicated, by measuring the distance along a radial line of the spline shaft between the intersection of the line of action and the line representing the tops of the hob teeth and the root of the spline.

Eliminating Fillet at Root of Spline: The fillet at the root may be practically eliminated by making the hob over size and cutting away in a circular form the outside diameter at the middle, as shown in Fig. 4. The minimum amount over size in radius can be determined by measuring, along a line perpendicular to the axis of the hob, the distance between the outside of the conven-



Figs. 1, 2 and 3. Method of Laying Out Hob Tooth Profile for Straight-sided Splines

tional hob and the intersection of the line of action with the root circle of the spline.

Let R_r = root radius of spline;
H = lead angle of hob;
R_h = radius of form of outside of hob.

Then,

$$R_h = \frac{R_r}{\cos^2 H}$$

The outside of the hob blank would be turned to form. The roughing out of the thread and the cutting of the gashes, and also the relief of the sides of the hob teeth, would be done in the usual manner. The relief of the cylindrical portion of the outside of the hob would also be done in the usual way. In addition, the curved section of the outside of the hob would be relieved by a form tool, and this relief would be done without any lead, or movement in an axial direction.

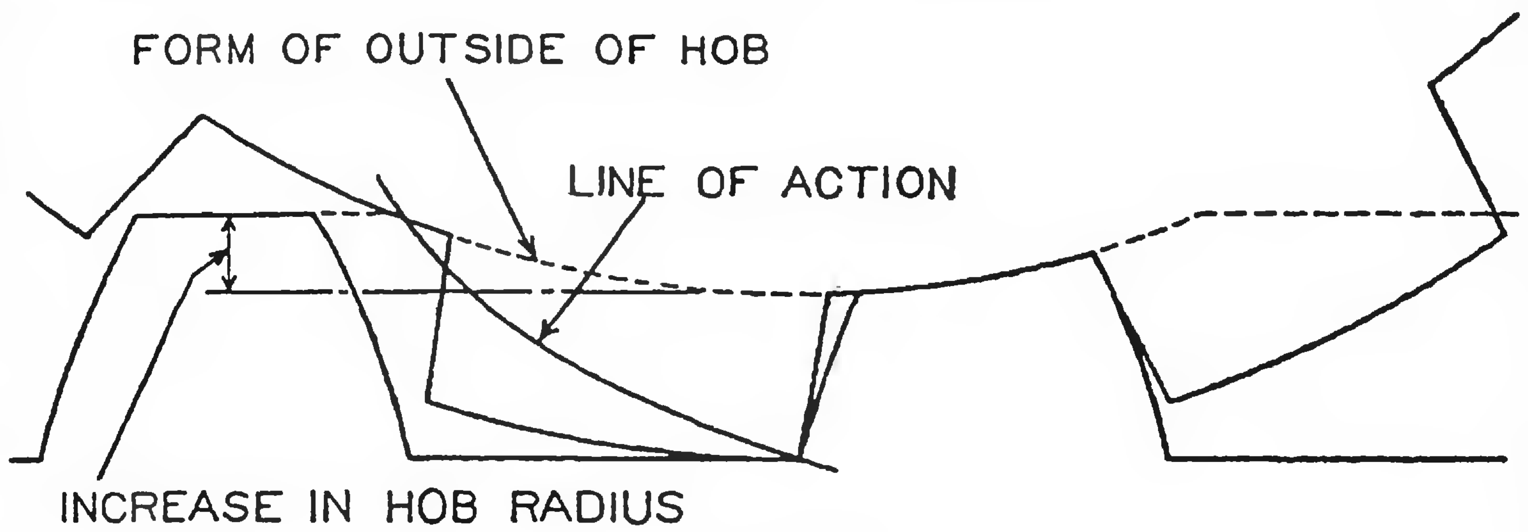


FIG. 4

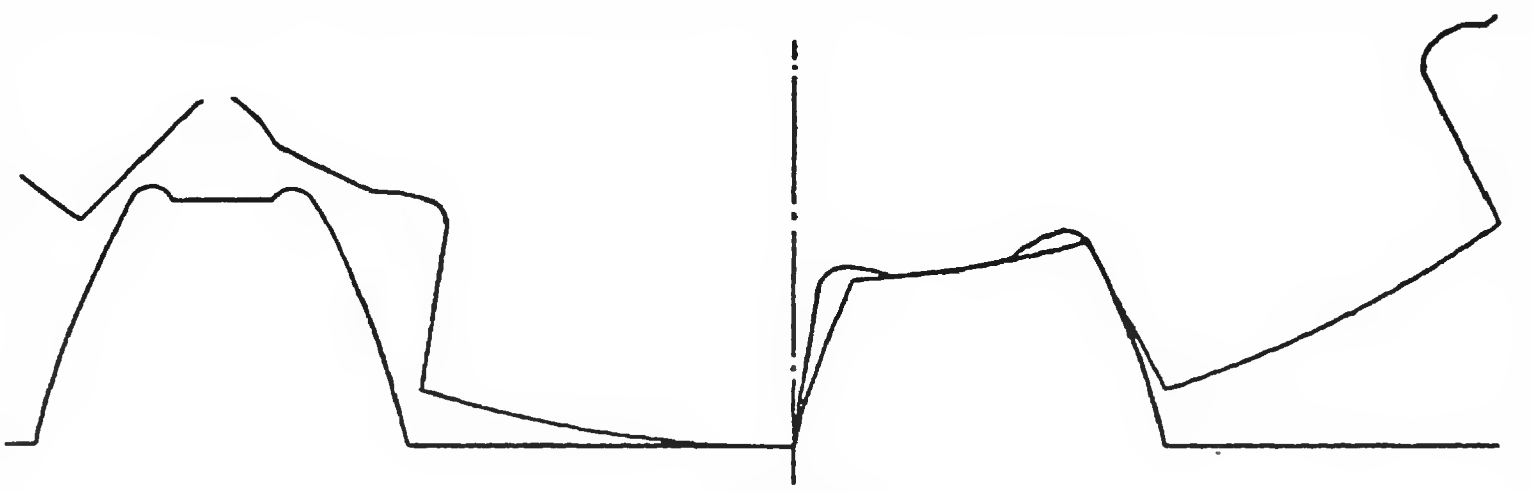


FIG. 5

Fig. 4. Modification of Hob Form to Eliminate Fillet at Root of Spline. Fig. 5. Hob Modified to provide Grinding Clearance at Root of Spline

Clearance at Root of Spline: A hob of this type could also be made to cut grinding clearance at the root of the spline, as shown in Fig. 5. In this case, the relieving tool for the sides of the hob teeth would be made to relieve the tops also. The relief of the outside of the central part of the hob would then be obtained as before.

Hobs, Taper. Hobs that are tapering on the leading end and that feed tangentially are especially adapted for cutting worm-gears of large helix angle. The use of a taper hob makes it possible to cut worm-gears more rapidly than with a fly-cutter, and also very accurately, provided the hob itself is accurate. The

taper-hob method also increases the rate of production as compared with the use of straight hobs which are fed in radially. In the taper-hob method, the rotation of the hob relative to the blank, as the hob moves tangentially, is such as to advance or screw the hob slowly along its own thread. The action of the hob is the same as that of a fly cutter, and machines adapted for the fly-cutter method may also be equipped with taper hobs. The leading teeth on the hob are tapering, and they should be designed to increase progressively in width as well as in height from the small to the full-size end. The tapering or leading end performs a roughing operation, whereas the full-sized teeth take light finishing cuts, thus preserving their accuracy and insuring well formed teeth. The tangential feeding movement continues until the large end of the hob passes out of contact on the side opposite the starting point.

Hob Taps. Hob taps are, as a rule, only intended for final finishing or sizing of the threads in dies. For this reason, their construction differs from that of ordinary hand taps. They are merely used for burring a thread already cut with ordinary taps. Straight hob taps are not relieved either on the top or in the angle of the parallel portion of the thread. Two or, at most, three threads, however, are chamfered at the point of the tap, and these chamfered threads are relieved on the top of the thread the same as ordinary hand taps.

Hoepfner Process. Two processes for the electrolytic production of metals are known as "Hoepfner" processes, from the inventor. One is the Hoepfner process for the electrolytic production of copper directly from its ore. In the Hoepfner zinc process, the zinc ore is first roasted, the zinc dissolved, and deposited by electrolysis, with insoluble anodes.

Hoisting Rope. Hoisting rope is made from 6 strands of 19 wires each, and is used for elevators of all kinds, mines, conveyors, derricks, etc. The wires are smaller than those used in the 6 by 7 haulage rope and are, therefore, not as well suited to resist abrasive action, but the rope can be more easily bent over sheaves and drums. *Special flexible hoisting rope* consists of 6 strands with 37 wires each, and is used for cranes, counterweights, dredges, and similar purposes. It possesses greater flexibility than the ordinary hoisting rope and can be bent over smaller sheaves, but is not suitable for use where it would be exposed to a great deal of external wear, because the wires are of small size and rapidly wear off. *Extra-flexible hoisting rope* is made from 8 strands of 19 wires each, and is used for practically the same purposes as special flexible hoisting rope. It has about the same flexibility as this rope but is not as strong for a corresponding diameter, because it has a larger central hemp core.

Hoisting Slings. Slings for hoisting are made of chain, wire rope, or manila rope.

Chain Slings: Chain slings are used to the greatest extent, because they are flexible and lend themselves readily to most of the hoisting operations met with in industrial work. Care must be taken, however, in the use of these slings, inasmuch as frequent strains slowly weaken the chain by crystallization, a condition which, though serious, is not readily visible. Weakness caused by surface wear or the slight opening of a single link is also likely to escape notice. Breakage of single links occurs often in cheap chains insecurely welded. Only the very best tested chain should be used.

Strength of Chains: In calculating the strength of chains, it should be observed that the strength of a link subjected to tensile stresses is not equal to twice the strength of an iron bar of the same diameter as the link stock, but is a certain amount less, owing to the bending action caused by the manner in which the load is applied to the link. The strength is also reduced somewhat by the weld. The following empirical formula is commonly used for calculating the breaking load, in pounds, of wrought-iron crane chains:

$$W = 54{,}000D^2,$$

in which W = breaking load in pounds and D = diameter of bar (in inches) from which links are made. The working load for chains should not exceed one-third the value of W, and, in many cases, it should be less. When a chain is wound around a casting and severe bending stresses are introduced, a greater factor of safety should be used.

Wire Rope Slings: Wire rope is often used for slings. Undue wear is promptly shown by broken or worn wires on the surface, which gives warning that the rope is in an unsafe condition. A wire rope sling is also stronger than a chain sling of equal size and weight. Wire rope, however, should be of the best material. By substituting the better grades of steel rope, much smaller, lighter, and more easily handled slings can be employed. Wire rope for general service is usually composed of six strands of wires wound about a hemp core to make the rope pliable and to provide a cushion to reduce internal friction of the wires. When used in proximity to heat, however, as when handling molten metal, wire rope slings provided with a soft iron core, even if the slings are less flexible, should be used. In such service a hemp center may be destroyed and the rope deformed.

Spliced ends are more dependable than clamped ends. Load strains which stretch the rope slightly reduce its diameter to a certain extent, and the ends are likely to slip through the clamps. Splices should always be made by experts. Small plants may not

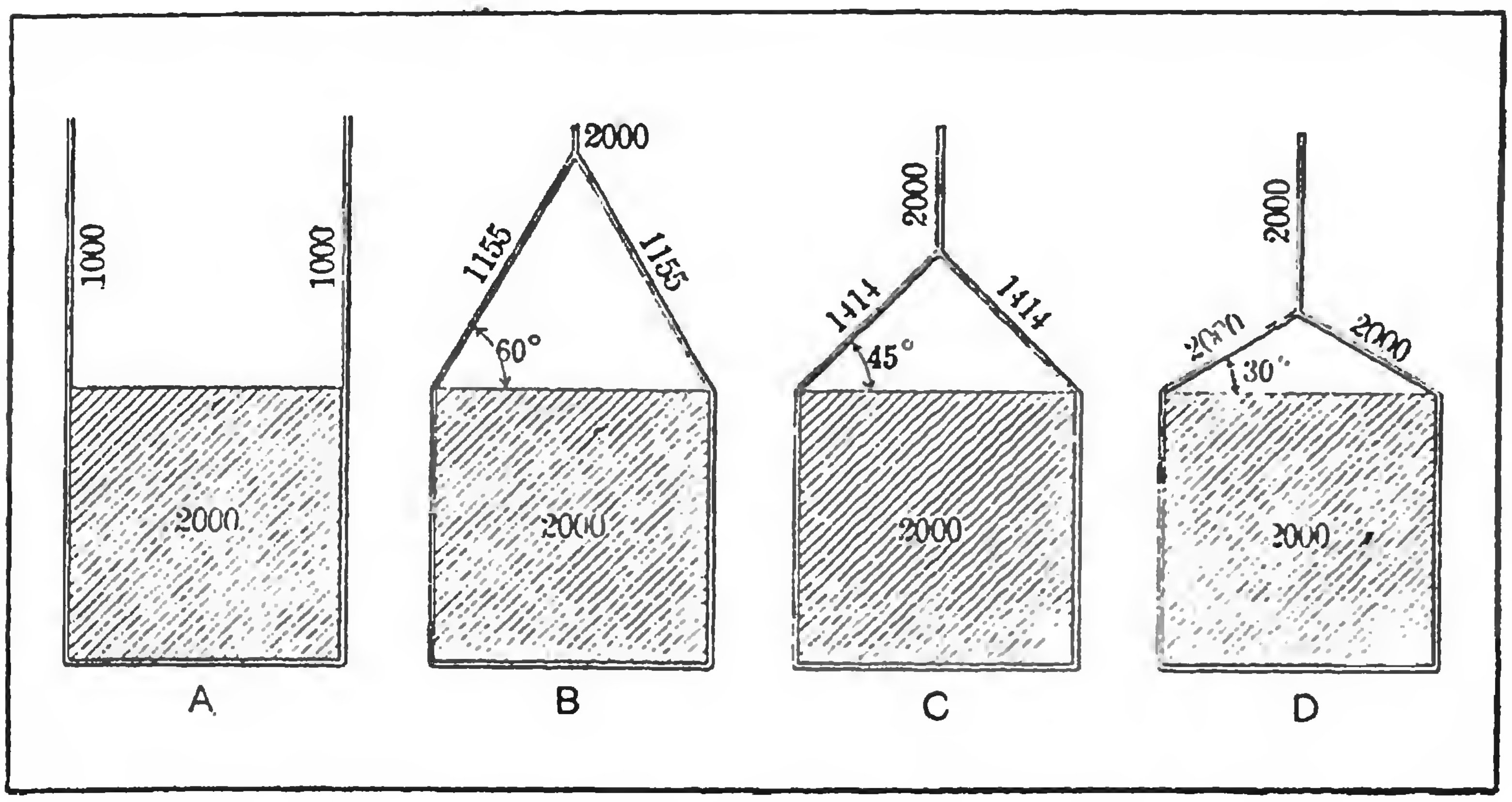
be properly equipped for splicing wire rope, in which case it is desirable to have this work done at wire rope factories, where it can be done well, and at small cost. It is often advisable to wrap the splice closely with soft wire, not to increase its strength but to protect the hands of the workmen from protruding wire ends. Instead of splicing the ends, forged steel sockets with hooks, eyes, or other fittings are frequently secured to the rope by spreading the wires in the socket and pouring zinc into it, between and around the wires. Sockets should also be attached by experts to insure secure connections. Wire rope manufacturers are equipped with special facilities for doing this work economically.

Manila Rope Slings: Manila rope is much weaker than wire rope, wears easily, and cannot be utilized where it would be exposed to flame or to charring temperatures. It weakens if allowed to remain wet, and should, therefore, be promptly dried. Although the strands are easily cut if the rope is used for handling sharp-cornered loads, the frayed condition of the rope gives prompt warning of undue wear and weakness. If manila rope slings are to be employed, it is advisable to buy the best long-fibered rope obtainable. The splices must be carefully made. Manila rope should never be looped with wire rope, as the smaller wire rope will cut through the strands of the soft manila rope.

Hoisting Sling Application to Load. The method of attaching slings to the load and to the hook of the hoisting cable is of great importance; and this part of the work should be entrusted only to experienced and responsible persons. Loads may often be safely hoisted by the use of a single sling, but in other cases two or three slings may be required, the number depending not only upon the weight of the load but also upon its shape. The stresses thrown upon slings and ropes vary a great deal with conditions and are often influenced to a marked degree by circumstances which the casual observer might consider trivial and unimportant. In particular, the inclination or obliquity of the sling, in those parts which lie between the supporting hook and the points at which the sling first touches the load, must be carefully considered, as it is a highly important feature in connection with safety.

In order to emphasize the effect that the obliquity of the sling has upon the intensity of the stress, and to avoid the necessity of repeatedly qualifying statements regarding the allowance for the stiffness of wire cables and for other circumstances, assume that the sling is perfectly flexible, and also that the load is symmetrical in shape and symmetrically supported, and that the branches of the sling (between the hook and the load) are equal

in length and equally inclined. For simplicity, also assume that the total load to be supported is 2000 pounds in each case.



Views showing Variation in Sling Stresses resulting from Different Angles

Under these conditions, if the ends of the sling are exactly vertical, as at *A* (see accompanying illustration), the stress on each end will evidently be 1000 pounds. If the ends are inclined, however, as shown at *B, C,* and *D,* the stress upon each one will be greater than 1000 pounds in every case, and it will increase as the obliquity of the ends increases—that is to say, as they become more and more inclined toward a horizontal position. This is because the stress on each of the inclined ends must have a vertical component equal to 1000 pounds; and as there must also be a horizontal component whenever the sling stands obliquely, the total tension in each of the inclined ends must always exceed 1000 pounds.

If the sling is of such a length that its ends, between the hook and the load, are inclined to the horizontal at an angle of 60 degrees, as indicated at *B,* the stress on each side will be 15.5 per cent greater than it would be if the sides were vertical; that is, each side will be subject to a total stress of 1155 pounds. To find the stress on each side, multiply one-half of the load by the cosecant of the angle with the horizontal. If the sides of the sling make an angle of 45 degrees with the horizontal, as shown at *C,* the tension on each of them will $= \frac{2000}{2} \times 1.4142 = 1414$ pounds. If the angle is 30 degrees with the horizontal as shown at *D,* each side will be subject to a stress of 2000 pounds. The

stress will continue to increase in a still more rapid ratio as the angle is decreased and when the sides of the sling approach the horizontal position quite closely, the stress upon them may become very great indeed. For example, if the sling were so short that its sides made an angle of only 5 degrees with the horizontal, each side would have to support a stress of 11,474 pounds.

These figures show very clearly the importance of giving careful attention to the inclination of the free ends of the sling. Men engaged in hoisting often take it for granted that the tension on a sling is everywhere the same, and if the sling be strong enough to support the load in safety when the ends are vertical, they assume that it is safe to hook it around the load in any way whatever. The sling should always be long enough to allow the ends to be at least as steep as shown at *C*, or, in other words, the ends should never make an angle of less than 45 degrees.

Hoists. The hoists used in machine shops and various classes of industrial plants, for lifting heavy parts, may be broadly classified as *hand-operated* and *power-operated* hoists. The common types of power-operated hoists are driven either by an electric motor or a pneumatic motor; with the so-called "air hoists," the load is lifted by the direct application of air pressure in a cylinder containing a piston that is attached to the lifting member of the hoist. The *differential hoist* or chain block, which was invented in 1854 by Thomas A. Weston, is based upon the principle of the Chinese windlass, an endless chain being substituted for the windlass rope and iron sheaves for the wooden drum. The chain hoist commonly known as the "screw" or "screw-geared" type, is so named because the power is transmitted from the hand chain to the load chain through a worm or screw which meshes with a worm-wheel. The spur-geared type of chain hoist is now used extensively and, if properly designed and built, is efficient.

Many *electric hoists* are equipped with motor-driven trolleys, some of which are controlled from the floor by pendant cords, while others have an operator's cage. When an electric hoist is not attached to a trolley, it is usually provided with a hook so that it can readily be suspended from a crane, or wherever the hoist is needed. The hoist is controlled by pendant cords or chains from the floor, connected with a variable-speed controller which operates in conjunction with the brake.

The air-motor or pneumatic, geared type of hoist is equipped with some form of air motor which drives the lifting drum through suitable reduction gearing.

Air Hoists: There are three general classes of *air hoists* of the cylinder type. With the *single-acting type*, compressed air is admitted to the lower or stuffing-box side of the piston only, and,

when lowering the hoist, this air is exhausted. The *air-balanced type* of hoist is so arranged that there is full air pressure on the stuffing-box side of the piston at all times. The load is hoisted by exhausting air from the space above the piston, and is lowered by admitting air above the piston; the unbalanced area due to the space occupied by the piston-rod aids in forcing the piston downward. The advantage of this arrangement is accuracy of control. The *double-acting type* differs from the balanced type in that air may be admitted and exhausted from either side of the piston, so that the latter may be moved in either direction with equal power. Thus, with a balanced hoist, there is a constant pressure on one side of the piston and a variable pressure on the other, whereas, with a double-acting type, the pressure on either side of the piston may be varied in accordance with the amount of the load and the direction in which the force must be applied. For this reason, hoists of the double-acting type are used whenever either a pushing or pulling effect may be required.

Hold-Back Dog. See Dogs or Drivers.

Hollow-Blast Grate. This is a furnace grate designed especially for the burning of wood refuse, such as sawdust, bark, and chips, which cannot be easily burned on an ordinary form of grate. The grate consists of a series of hollow bars connected with a blast fan, air being admitted to the fire through openings in the upper surfaces of the bars.

Hollow-Mills. Hollow-mills are used for reducing the diameter of round stock and are frequently employed in connection with spring screw threading dies, taking a cut preceding the die. Hollow-mills are usually made adjustable, the adjustment being obtained with a clamp collar the same as in spring screw threading dies.

Holly Method. This is a method of operation of Bessemer converter plants in which the burned-out converter is removed by a crane or car and one that has been lined and dried in a separate shop is substituted for it.

Homo-Polar Machine. See Acyclic Machines.

Honing Process. The hone-abrading process for obtaining cylindrical forms with precise dimensions and surfaces can be applied to internal cylindrical surfaces with a wide range of diameters such as engine cylinders, bearing bores, pin holes, etc. and also to some external cylindrical surfaces. The process is used to: (1) eliminate inaccuracies resulting from previous operations by generating a true cylindrical form with respect to roundness and straightness within minimum dimensional limits; (2)

generate final dimensional size accuracy within low tolerance, as may be required for interchangeability of parts; (3) provide rapid and economical stock removal consistent with accomplishment of the other results; (4) generate surface finishes of a specified degree of surface smoothness, with high surface quality.

Honing may be employed to reduce bore diameters by as much as 0.100 inch or as little as 0.001 inch. The amount of stock removed by the honing process is entirely a question of processing economy. If other operations are performed before honing then the bulk of the stock should be taken off by the operation that can do it most economically. In large diameter bores that have been distorted in heat treating, it may be necessary to remove as much as 0.030 to 0.040 inches from the diameter to make the bore round and straight. For out-of-round or tapered bores, a good "rule of thumb" is to leave twice as much stock (on the diameter) for honing as there is error in the bore. Another general rule is: For bores over one inch in diameter, leave 0.001 to 0.0015 inch stock per inch of diameter. For example, 0.002 to 0.003 inch of stock is left in two-inch bores and 0.010 to 0.015 inch in ten-inch bores. Where parts are to be honed for finish only, the amount of metal to be left for removing tool marks may be as little as 0.0002 to 0.001 inch on the diameter.

In general, the honing process can be employed to remove stock from bore diameters at the rate of 0.009 to 0.012 inch per minute on cast-iron parts and from 0.005 to 0.008 inch per minute on steel parts having a hardness of 60 to 65 Rockwell C. These rates are based on parts having a length equal to three or four times the diameter. Stock has been removed from long parts such as gun barrels, at the rate of 65 cubic inches per hour. Recommended honing speeds for cast iron range from 110 to 200 surface feet per minute of rotation and from 50 to 110 lineal feet per minute of reciprocation. For steel, rotating surface speeds range from 50 to 110 feet per minute and reciprocation speeds to be used depend upon the size of the work, the amount and characteristics of the material to be removed, and the quality of the finish desired.

Hook Bolt. See Bolts.

Hooke's Coupling. Hooke's coupling, generally known as the "universal joint," is employed for connecting two shafts, the axes of which are not in line with each other, but which merely intersect at one point. Sometimes two shafts, the axes of which are in different planes, and, hence, do not intersect at any point, are connected with an intermediate shaft which is joined to each of the two shafts by universal joints. Many designs of flexible shafts are simply a combination of universal joints.

Hookes Law. Hooke's Law states that stress is proportional to strain. The law was first formulated by the English scientist Robert Hooke in 1678 after repeated tests with structural materials showed that within certain limits the elongation of a bar of material was proportional to the tensile force causing its elongation.

Hook-Tooth Sprocket. This is a sprocket for link-belting, used to transmit power from or to a chain running in a straight or nearly straight line. It is sometimes employed as an idler for returning a horizontal slack chain, if the drive is intermittent and there is a tendency for the chain to jump off an ordinary sprocket.

Horning and Wiring Press. Presses of this general type are used in the manufacture of tin pails, coffee pots, baking pans, and similar articles. For many operations on such parts, the work must be inserted over a projecting arm or horn which may be either cylindrical, tapering, square, or of a special shape. While supported by this horn or die, the operations are performed by the punch.

Horsepower. In mechanics, *work* is the product of force by distance, and is expressed by a combination of units of weight (force) and distance, as inch-pounds, foot-pounds, foot-tons, etc. *Power,* in mechanics, is the product of force by distance divided by time, or the performance of a given amount of work in a given time, and is expressed as inch-pounds per minute, foot-pounds per minute or second, etc. The term *power* is frequently used by writers on mechanics to designate a *force.* In connection with the so-called "mechanical powers" — the lever, wheel and axle, wedge, screw, etc. — it is usual to speak of the applied force as the power; this is, however, not strictly correct, as power should always, in mechanics, be used in accordance with the definition given above. *Horsepower* (abbreviated H.P.) is the unit of power adopted for engineering work. One horsepower is equal to 33,000 foot-pounds per minute, or 550 foot-pounds per second.

The *metric horsepower,* used in countries where the metric system is employed, is equal to 75 kilogrammeters per second, or 542.5 foot-pounds per second, or 32,550 foot-pounds per minute. The *kilowatt,* used in electrical work, equals 1.34 horsepower; or one horsepower equals 0.746 kilowatt. The horsepower unit was introduced by James Watt, the great improver of the steam engine, for the purpose of designating the power developed by his engine. It is said that he had ascertained by experiments that

an average cart horse could develop 22,000 foot-pounds of work per minute, and being anxious to give good value to the purchasers of his engines he added 50 per cent to this amount, thus obtaining (22,000 + 11,000) the 33,000 foot-pounds per minute unit by which the power of steam and other engines has ever since been estimated.

Electrical Equivalent: The British Association for the Advancement of Science adopted, as early as 1873, 746 watts as the equivalent of the British and American horsepower, and 736 watts as the equivalent of the metric or Continental horsepower. In a circular issued by the United States Bureau of Standards, it is stated that in all future publications of this bureau the former value, 746 watts, or 0.746 kilowatt, will be used as the exact equivalent of the English and American horsepower. For scientific work, it is quite important to have the horsepower thus standardized by being expressed in the so-called "absolute system of measurement," because the common definition of 550 foot-pounds per second is scientifically correct only at a certain latitude and altitude, on account of the fact that the pound-weight, as a unit of force, varies in value as g, the acceleration of gravity, varies. The horsepower when expressed as 746 watts is equal to 550 foot-pounds per second at 50 degrees latitude and at sea level. See Steam Engine Horsepower Rating.

Horsepower, Belting. See Belt Power-transmitting Capacity.

Horsepower, Boiler. See Boiler Capacity Rating.

Horsepower Formula for Automobile Engines. Brake horsepower rating is usually based upon the maximum speed of 3400 to 3600 R.P.M., although some manufacturers' power ratings are based upon speeds up to 4000 R.P.M. The horsepower of a motor may be determined approximately by the following formula in which D = cylinder diameter, in inches; S = length of stroke, in inches; and N = number of cylinders.

$$\text{Horsepower} = 0.32\, D^2 SN$$

The constant 0.32 may range from 0.3 to 0.37 for the power ratings of different manufacturers, but 0.32 is a fair average.

Horsepower-hour. A unit of work or energy equivalent to one horsepower acting one hour. 1 horsepower-hour = 0.746 kilowatt-hour = 1,980,000 foot-pounds = 2545 B.T.U. (British thermal units) = 2.64 pounds of water evaporated at 212° F = 17 pounds of water raised from 62° to 212° F.

Horsepower, Metric. See Metric Horsepower.

Hose Couplings. The American Standard for Hose Coupling Screw Threads includes the following classes and nominal sizes:

Garden and Similar Hose: The nominal sizes are ½, ⅝, and ¾ inch, and the number of threads per inch is 11½ in all cases.

Chemical, Engine, and Booster Hose: The nominal sizes are ¾ and 1 inch, with 8 threads per inch for both sizes.

Fire Protection Hose: There is a single size of 1½ inches in this standard, with 9 threads per inch.

Steam, Water, Air, Oil, and All Other Hose Connections: There are six nominal sizes as follows: ½- and ¾-inch sizes, with 14 threads per inch; 1-, 1¼-, 1½-, and 2-inch sizes, all with 11½ threads per inch.

These hose couplings all have the American Standard form of thread.

Hose Couplings, Fire. The National (American) Standard Fire-hose Coupling Screw Thread applies to fire hose couplings, hydrant outlets, stand-pipe connections, and other fittings on fire lines having nominal inside diameters of 2½, 3, 3½, and 4½ inches. The screw thread for the 2½-inch inside diameter has 7½ threads per inch and a pitch diameter of 2.997 min. and 3.013 max.; the 3-inch size has 6 threads per inch and a pitch diameter of 3.5306 min. and 3.5486 max.; the 3½-inch size has 6 threads per inch and a pitch diameter of 4.1556 min. and 4.1736 max.; the 4½-inch size has 4 threads per inch and a pitch diameter of 5.6235 min. and 5.6485 max. The thread form in all cases is the American Standard (formerly known as U. S. Standard).

This fire-hose coupling thread standard has been approved and adopted by the American Water Works Association, Brass Hose Fittings Manufacturer's Association, Bureau of Standards—U. S. Department of Commerce, International Association of Fire Engineers, National Board of Fire Underwriters, National Fire Protection Association, National Screw Thread Commission, Railway Fire Protection Association, The American Society of Mechanical Engineers, The National Firemen's Association of the U. S., and other organizations.

Hot Bearings. Investigation has shown that the main reasons for excessive heating of babbitted bearings are: 1. Shrinkage or contraction of the babbitt. 2. Shrinkage strains set up in the babbitt metal liner by the unequal distribution of the babbitt metal over the shell. 3. A lack of contact between the babbitt metal liner and the cast-iron or cast-steel shell. 4. The lubricant becomes partially deflected into the wrong place.

Hot-Milling. Milling off a small amount of metal from the cutting edges of forged tools while they are still at the forging heat is known as "hot-milling" and is used in the production of rock drill bits. On ordinary forged rock drill bits, the surfaces

are scaled and pitted, with discolored patches which indicate that changes have taken place in the composition of the surface material. Hot-milling removes this coating and exposes the unaffected material, so that the bit can be properly hardened. The hot-milling operation also brings the bits to the correct shape and size. An interesting point is that a lower temperature can be used when hardening a hot-milled bit, as the quenching medium does not have to penetrate the scale and skin left by the forging operation.

Hot-Pressed Brass Parts. Hot-pressed parts are formed in dies by means of a press which exerts enough pressure on a heated slug of forgeable brass to cause the metal to flow and fill the die cavity. The term "hot pressing" is generally applied when some type of power press or hydraulic press is used, whereas, if brass parts are formed in dies under a drop-hammer or steam hammer, the process is known ordinarily as brass forgings. Both methods produce die-formed brass parts to replace small brass castings or machined parts such as are produced on screw machines or turret lathes.

The brass slugs, prior to hot-pressing, are heated in a gas, oil or electric furnace to a temperature of about 1450 degrees F.: then the heated slug is inserted in the die and the part is pressed. The pressed pieces are usually subjected to a pickling process to produce a glossy bright surface; they resemble die castings and the surfaces, in many cases, are smooth enough to permit polishing without previous grinding. Hot-pressed parts can be held to limits of plus or minus 0.002 inch on a diameter not exceeding 1 inch. On a diameter of from 1 to 2 inches, the sizes will vary by plus or minus 0.004 inch. Smaller sections than 1 inch can be held closer. Shoulders can be held to plus or minus 0.002 inch.

Alloys for Hot Pressing: Brass containing 60 per cent copper and 40 per cent zinc is quite forgeable and suitable for the manufacture of hot-pressed parts. The extruded brass shapes now on the market are also suitable for hot pressing; moreover, if the cross-section selected conforms approximately to the shape of the die, the forging of the slugs is facilitated. The slugs, however, should not conform too closely to the shape of the finished forging because the metal must flow under pressure to get the best results. Other metals which can be hot pressed include aluminum, dur-aluminum, monel metal, and similar compositions of a forgeable nature.

Presses Used: The percussion press, which has a screw-operated slide and a friction drive, is particularly adapted to hot-pressing of brass and steel parts. The friction drive gradually accelerates the flywheel (located at the upper end of the screw)

and the cumulative quality of the blow delivered causes the heated slug to flow and completely fill the die cavity. The part is finished with one stroke of the press and the slide returns automatically to its upper position.

Both single- and double-acting crank presses, and hydraulic presses, have also been used for hot pressing.

Dies Used for Hot Pressing: Hot-pressed brass parts may be produced in three types of dies. *Open dies,* similar to those used in drop forging, may be employed, but the forged parts have a flash or fin which must be removed by trimming. In using *extrusion dies,* the material is confined and forced by the punch to pass through a smaller opening in the bottom, assuming that the forging has a large head and a small stem. In forging a shell or bushing, the metal can be forced to rise up around the punch. *Confined dies* represent the third type. The descending punch closes the die and the metal is compelled to flow in all directions, thus filling the die cavity. It may be necessary to make confined dies in sections in order to remove the finished piece. For some work, there is an advantage in lubricating the dies. See Brass Forging.

Hot-Pressed Steel Parts. A hot-pressing process similar in principle to that employed in hot-pressing brass parts may be applied to a variety of small steel parts. In hot-pressing steel, the slugs of steel are heated to about 1800 degrees F. and are then pressed to the desired shape in tungsten steel dies having cavities corresponding to the form required. The dies have tungsten steel inserts which are backed up by machine steel. See also Cold Extrusion.

Hot Shortness. A term used to describe the brittleness in metals in their hot forming range.

Hot Top. In the manufacture of steel, the molten metal from the crucible, converter, or electric furnace is poured into ingot molds. The impurities which float on the top of the molten metal are carried to the top of the mold, which is fashioned with a temporary "hot top" made of some refractory material. By this means the top of the ingot containing the impurities can be sheared off after the ingot is cold.

Hot-Wire Meter. This is an instrument for measuring electric current in which the current passes through a straight wire. the amperage being measured by the expansion of the wire caused by the heating effect of the current. The expansion is transmitted by a lever to an indicating needle. The thermocouple type of meter is now largely used in place of the hot-wire meter because of lower power loss and greater sensitivity. See Ammeter.

Hot-Working. Hot-working is the plastic deformation of metals at temperatures above the recrystallization or work-hardening range. Advantages of hot-working include: low resistance to plastic deformation, a high degree of ductility in the product, refinement of coarse grains, and the improvement of mechanical properties due principally to grain refinement. Among the posible disadvantages to hot-working are: oxidation or scaling of surfaces (which can often be controlled satisfactorily), the relatively poor surface finish produced, and the impracticability of maintaining close tolerances with some methods.

"Hot-Work" Steels. The term "hot work" is commonly applied to steels adapted for forging dies or other operations on heated metal. In the selection of die steels for use in modern forging equipment, special consideration must be given to the resistance of the steel to heat, abrasion, and pressure. It is not possible to select a hot-work steel that will possess maximum ability to meet all of these service conditions. In one case, it will be necessary to select a steel having maximum resistance to heat and to abrasion. In another case, the ability to withstand pressure, shock, and fatigue will be the governing factor.

Hot-work steels may be classified broadly as the tungsten (or molybdenum) type and the chromium type. The accepted usage of the term "hot-work steels," covers all steels used in manufacturing dies, shears, punches, etc., for use in forging machines, presses, hot trimmers, etc. The hot-working of metal is also performed extensively under forging hammers equipped with die-blocks made of chromium-nickel-molybdenum steel.

Tungsten steels offer excellent resistance to heat and abrasion. Molybdenum possesses heat-resisting properties similar to tungsten, and is sometimes used in analyses in place of tungsten in quantities equal to about one-half the tungsten content. Tungsten is an expensive element, but on jobs where dies operate at high temperatures, tungsten steels prove the most economical. Chromium is next to tungsten and molybdenum in heat-resisting qualities. Chromium steels are used largely in automatic hot-working machines where resistance to repeated impact and to heat is important.

Hoyle's Metal. Hoyle's metal is a bearing metal of the lead-tin-antimony alloy class, composed of 42 per cent of lead, 46 per cent of tin, and 12 per cent of antimony.

Hub Method of Die-Sinking. The "hub" or "hob" method has long been employed for making dies such as are used in producing coins, medals, and various products of the silversmithing and jewelry trades. A hub is used, which is in the form of a punch

and has a shape corresponding to the impression required in the die. In other words, the hub, at its formed end, is a duplicate in hardened tool steel, of the part to be molded in the die. While this hub must be made accurately and be given a fine finish, it is, of course, much easier to produce than would be a cavity or impression of corresponding shape. Furthermore, after the hub is made, it can be used to advantage in reproducing duplicate impressions in a number of different dies. The hub is hardened so that it will withstand the extremely high pressures employed in connection with the production of dies by this method. In a general way, the method consists in forcing the hub into the unheated die blank by means of hydraulic power so that the shape of the hub is reproduced in the die impression.

Humidity Measurement. See Hygrometer.

Humid Process. In assaying, the humid process, also known as the "wet process," is a method of testing alloys, especially for ascertaining the quantity of silver or gold contained. The process consists in dissolving the metals by acids and afterwards precipitating them.

Hunting. Hunting, in electrical engineering, is a periodic increase or decrease in the speed of synchronous machinery operating in parallel, such as generators or motors. It may be due to several causes, such as irregular action of the prime movers, or a variation of the supply voltage, as caused, for example, by the drop due to a relatively high resistance and reactance in the supply line. A short circuiting or amortisseur winding in the pole faces is one means of damping out hunting action.

Hunting Tooth. When one of two meshing gears is provided with one more tooth than it would have if the numbers of teeth in the two gears were in an even ratio to each other, this extra tooth is commonly known as a "hunting tooth." For example, if a driven shaft is required to revolve three times as fast as the driving shaft, this result could be obtained by using driving and driven gears having 72 and 24 teeth, respectively. Instead of using this exact ratio, many millwrights, when installing cast gears, would use a driving gear having 73 teeth instead of 72, and a driven gear of 24 teeth. These numbers are very close to the desired ratio, but, as they do not have a common divisor, each tooth of one gear will mesh with all of the mating teeth one after the other, instead of meshing with the same teeth continually. The theory is that when the teeth mesh progressively in this manner, thus distributing the wear, all of the teeth will eventually be worn to some indefinite, but comparatively true, shape. To illustrate the action, any two teeth which happen to meet during the first revolution will be separated by one tooth

space at the completion of the second revolution, by two tooth spaces at the end of the third revolution, and so on; consequently, one tooth may be said to "hunt" the other, and hence the name "hunting tooth."

Hydracid. This is an acid which does not contain oxygen, but in which hydrogen unites directly with the principal element.

Hydraulic Accumulator. An accumulator is essentially a pressure storage reservoir in which a noncompressible hydraulic fluid is retained under pressure from an external source. The fluid, under pressure, is readily available as a quick secondary source of fluid power and even though it may have been pumped into the accumulator in pulsations or an uneven flow, it will be discharged from the accumulator in a smooth even flow.

Among the types of applications for which accumulators are suitable are: (1) hydraulic shock suppression; (2) fluid make-up in a closed hydraulic system; (3) leakage compensation; (4) source of emergency power in case of power failure; and (5) holding high pressures for long periods of time without keeping the pump unit in operation. Accumulators are used in conjunction with hydraulic systems on large hydraulic presses, farm machinery, diesel engine starters, hospital beds, power brakes and landing gear mechanisms on airplanes, hatch covers on ships, lift trucks, and other devices and machinery too numerous to mention.

Hydraulic Jacks. Jacks of this type are especially adapted for lifting very heavy loads. There are many different designs and sizes that operate on practically the same principle. One of the most common forms of hydraulic jack is the vertical, inside pumping type. The head and interior of the ram form a reservoir from which the liquid is pumped beneath the ram for raising the jack, and to which the liquid is returned in lowering. When the liquid enters the pump from the reservoir, it is forced by the downward stroke of the piston through a lower check-valve into the cylinder and beneath the ram, which is forced upward because the pump is of small size, and owing to the leverage of the operating handle it is possible to exert considerable pumping pressure. The operating lever slips into a socket at the side of the head. This socket is mounted on a shaft which carries a short arm or lever inside of the head to which the pump piston-rod is attached. The Dudgeon *universal jack* has double pumps so that, if the load is light or if the ram must be extended some distance before the heavy load is encountered, the two pumps can be used together until the strain becomes excessive, when one pump is thrown out by a turn of the handle.

Hydraulic Presses. A hydraulic or hydrostatic press, is a machine by the use of which some forcing or pressing operation is performed by means of power transmitted through confined fluid under pressure. The hydraulic press was invented by Joseph Bramah, an Englishman, who, in conjunction with Maudslay, laid the foundation for the development of modern metal-cutting tools. The hydraulic press, as built by Bramah, was equipped with a stuffing-box and gland for packing the ram. This arrangement, however, retarded the return stroke and caused considerable trouble until Maudslay substituted the self-tightening cup-leather packing for the stuffing-box.

That fluids, when confined and subjected to pressure, follow a definite law, was first discovered in 1653 by a French scientist, Blaise Pascal, who wrote of the results of his hydrostatic investigations in a treatise on the equilibrium of fluids. By the application of Pascal's law, the development of a tremendous force exerted through a short distance becomes possible by the exertion of very small force through a proportionally longer distance. Advantage is taken of this principle in commercial hydraulic press and pump installations.

The press is frequently separate from the pump and may be located at considerable distance from it; the pump may be of any size and type suitable for delivering the necessary volume of fluid at the required pressure per square inch; pipe lines and valves may connect the pump and press; and accumulators or other machines or apparatus may also be connected to the system; but notwithstanding all these, when hydraulic communication is open from the pump plunger to the press cylinder, Pascal's law governs, theoretically, the relations existing between the press ram and the pump plunger. Practically slight allowances may be required to compensate for losses due to friction of the water in the pipes, friction of packings, leakage, and other minor losses.

The use of hydraulic presses is confined to no particular industry, nor to any particular class of service. Almost any pressure application or any combination of pressure applications may be produced in a suitable hydraulic press. Practical conditions have, however, limited the use of the hydraulic press mainly to machines in which great pressure is a prime requisite, leaving the field of light pressure requirements to be covered largely by mechanical power presses.

Hydraulic Ram. The hydraulic ram is used to raise water from a point below the source of supply to a point which may be considerably higher than the level of the spring, reservoir or part of a stream from which the water flows to the ram. The only power required to operate a hydraulic ram is that obtained from the

momentum of a moving column of water. The ram is so constructed that the water is allowed to flow intermittently, and each time its movement is suddenly stopped the kinetic energy is changed to pressure and utilized to force part of the water through a discharge valve and into an air chamber where air is compressed, and aids in forcing a relatively small quantity of the water out through the discharge pipe. When the ram is in operation, the water flows downward through the drive pipe and through the open waste valve *B* (see illustration) until the required velocity is obtained, when valve *B* is automatically closed. During its flow, the water has developed a certain amount of energy or momentum which, when the flow is suddenly stopped, causes the water to overcome the pressure against the top of the discharge valve *S* which opens and allows a portion of the water to enter the air chamber. Immediately, a rebound occurs and for a short interval water flows out through the discharge pipe. As soon as the movement of water in the drive pipe ceases, valve *B* is opened by the action of weight *H* acting through a cam surface at *G* against which lever *E* bears. The opening of this valve causes the water in the drive pipe to again flow rapidly downward and the cycle is repeated.

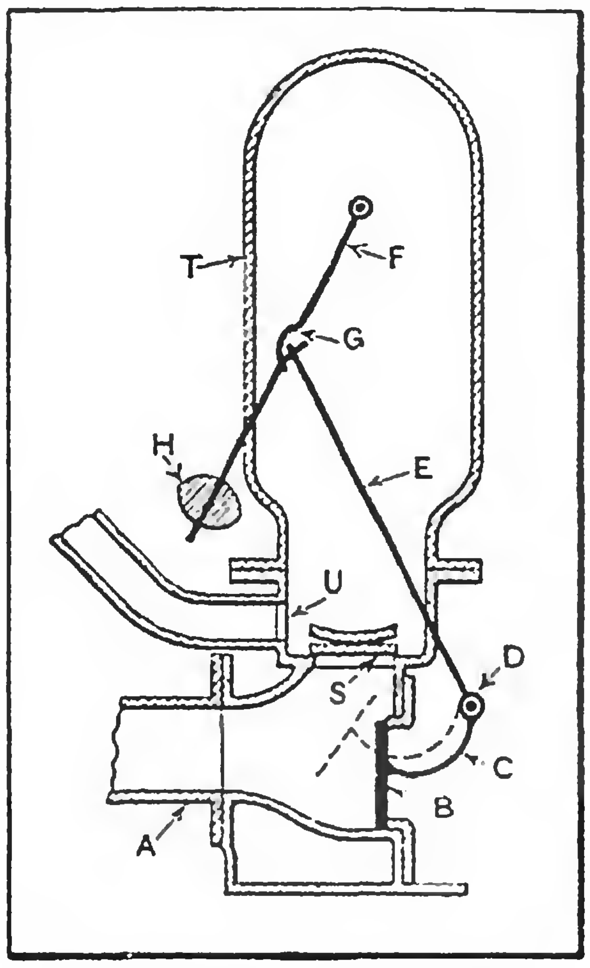


Diagram of Hydraulic Ram

Drive Pipe: The length of the drive pipe may vary from three to four times the height of the head to eight or ten times the height. According to one rule, if the head or vertical distance from the ram to the level of the source of supply is from 6 to 10 feet, the drive pipe should not be less than six times the height of the fall. If the head is less than 6 feet, the length of the drive pipe should equal from eight to ten times the head. For instance, if there is a head of 5 feet, the drive pipe should be from 40 to 50 feet long, according to this rule. A fall of 2 feet is usually considered about the minimum at which hydraulic rams will operate satisfactorily. The drive pipe should be as straight as possible and the bend near the ram should be a long gradual curve.

Discharge Pipe: The discharge pipe may vary in length from a few feet to hundreds of feet. Its diameter should vary from one-third to one-half the diameter of the drive pipe. The

straighter the pipe line, the better the performance of the ram.

Quantity of Water Delivered: The amount of water that a hydraulic ram will deliver is affected by the head of water or height of the fall, the quantity available, the height to which the water is elevated, and the friction in the pipes. In general, it is estimated that approximately one-seventh of the volume of water falling into the ram can be raised to an elevation five times the height of the fall, or one-fourteenth of the volume can be raised about ten times the height of the fall, and so on in like proportion according as the fall or height is increased or diminished.

Hydraulic Shears. Hydraulic shears which are used in connection with hydraulic intensifiers for giving the required pressure are designed and used for various purposes. Such shears are especially adapted for cutting off billets and blooms in rolling mills, and they are also used for shearing structural shapes.

Hydraulic Transmissions. Hydraulic transmissions are used in preference to mechanical transmissions on certain types of machines, either to drive the main working member or to provide a feeding movement for a tool or machine table. Hydraulic transmissions are now applied to many different types of machines and other mechanical devices, including various classes of presses; testing machines; mechanical stokers; cranes and hoists; ships' windlasses and steering apparatus; to certain types of machine tools, etc. In machine tool design the hydraulic transmission is utilized in preference to a mechanical transmission on certain types of machines partly with the idea of obtaining smoother action and greater flexibility of control. Hydraulic transmissions, for example, have been applied to broaching machines; to grinding machines to provide the traversing movement; to drilling machines, milling machines and some turning machines for supplying the feeding movements.

These systems, consisting of self-contained pumping and valve units, are now available for use on practically all types of machine tools. Although they are commonly called hydraulic or "fluid power" systems, no water is employed, the operating fluid being oil, which not only provides means for the hydraulic transmission of power, but also serves to lubricate the moving parts. The use of oil for transmitting power or movement to machine tables, slides, feeds, etc., has several advantages. The incompressibility of oil prevents the generation of heat and loss of energy from this source. The chemical stability of oil, its noncorrosive nature, and its lubricating properties are important advantages.

Hydraulic transmissions are designed for driven members hav-

ing either a constant or variable straight-line reciprocating movement or a constant or variable rotary motion. In the case of straght-line movements, the hydraulic pressure is applied to a plunger or piston within a cylinder, whereas, for rotary motion, a hydraulic or fluid power motor is used in conjunction with the pump. In both types of transmissions, the equipment must be designed to meet various operating requirements, as, for example, in regard to speed variations and method of controlling the speed changes or other movements; hence, both the pumps and motors are made in different types as well as in a large range of sizes.

Variable Displacement Pumps: With this type of pump, the stroke may be adjusted to obtain any volume from zero to maximum. Different types of hand and automatic power controls are employed, depending upon the type of machine and its operating requirements. Variable displacement pumps, in conjunction with cylinders and control valves, are applied to such machines as grinding, shaping, planing, honing and broaching machines; to presses, etc. Pumps of this type may be used in combination with fluid power motors when a variable rotary speed is required.

Constant Displacement Pumps: This type of pump has a fixed stroke so that the volume of oil delivered varies with the pump size and driving shaft speeds. Where variable speed is not essential or for applications requiring the repetition of a cycle, the constant displacement pumps are preferable. They are used for broaching and assembling presses, riveting machines, and for many other applications. These pumps may be used in conjunction with one or more fluid power motors.

Pumps of Duplex Type: The variable and constant displacement duplex pump is applicable when a variable-speed and high working pressure is required in conjunction with high-speed rapid traverse at low pressure. These pumps may be applied to transmissions on presses of different kinds, bending machines, riveting machines, etc.

Fluid Power Motors of Constant Displacement Type: This is a constant torque type of motor, the maximum torque being available at all speeds. When a constant displacement motor is used with a variable displacement pump to obtain a variable-speed and constant-torque transmission, the maximum horsepower transmitted is directly proportional to the motor speed. The use of these motors in conjunction with suitable pumps covers a wide range of applications. In many cases, two or more fluid motors may be applied to different parts of a machine, or they may be located on different floors, with the pump placed at whatever point is convenient in regard to the source of power. The fluid power is transmitted through pipe lines from the pump, thus greatly simplifying it as compared with a mechanical transmission.

Fluid Power Motors of Variable Displacement Type: These motors provide constant power with variable torque, the maximum power being available over a limited range of speeds. The torque decreases and the speed increases as the motor stroke is reduced. These motors, like the constant displacement type, may be applied to different parts of a machine or be installed on different floors. They are applicable also to a large variety of industrial drives.

Advantages of Hydraulic Transmissions: Transmissions of the hydraulic type may be used in preference to mechanical transmissions because of one or more of the following advantages, depending upon the type of machine: (1) Greater flexibility of control; (2) quick reversal of motion with practically no shock; (3) "slip" which compensates for overloads or unexpected obstructions; (4) practicability of locating transmission members with reference either to power application or the design of other parts; (5) use of relief or control valves to safeguard against overloading.

Hydraulic Vacuum Pump. This is an air pump which removes the non-condensible vapors from a condenser by hurling jets of water, approximately rectangular in cross-section, at a high velocity from a revolving wheel. The water jets rush through the discharge cone and diffuser in the form of a helix enclosing the vapors, which enter around the revolving wheel, between the jets or pistons of water. The hurling water is delivered under pressure by a centrifugal pump.

Hydrocarbon. Hydrocarbon is a general name for a number of chemical combinations of carbon and hydrogen, such as marsh gas, tar, pitch, naphtha, etc.

Hydrochloric Acid. Hydrochloric acid, also known as muriatic acid, is an aqueous solution of hydrogen chloride (chemical formula, HCl). In the mechanical industries it is used either alone, or mixed with other acids as an etching fluid. It is colorless when pure, but the commercial acid has a yellow tint, due to impurities. Concentrated acid contains 32 per cent of hydrochloride and has a specific gravity of 1.16. Dilute acid, containing about 18 per cent of hydrochloride, has a specific gravity of 1.09. Hydrochloric acid gives off poisoncus fumes if left open in the air, the fumes being chlorine gas. An antidote for chlorine gas poisoning consists of powdered chalk or soap dissolved in water.

Hydrofluoric Acid. Hydrofluoric acid is an aqueous solution of anhydrous hydrogen fluoride (chemical formula, HF). The acid dissolves glass, and can, therefore, be used as an etching

fluid for glass, a purpose for which it is commonly employed. It also attacks most metals, and can be used as an etching fluid for metal objects as well. The acid is a colorless fuming liquid, having a specific gravity of 1.25, when in a saturated solution. Gases given off by hydrofluoric acid are poisonous, and the acid also is injurious, if applied to the skin. As it dissolves glass, it is generally kept in lead-lined vessels. Hydrofluoric acid is also used for a quick pickle for hot castings. It is also used in conjunction with soda, as a water softening compound for boiler feed water. The acid attacks practically all materials that could be used as containers for it except lead, platinum, gutta-percha, and some clays. When etching glass by means of this acid, the glass is first coated by a light coating of melted paraffin or an etching varnish made from asphaltum and beeswax. In making this varnish the wax is first melted and the asphaltum stirred into it, after which the mixture is boiled until, upon cooling, it will harden readily.

Hydrogen. Hydrogen is a gaseous chemical element, the symbol of which is H, and the atomic weight, 1.008. The specific gravity, as compared with air, is 0.0694. Its specific heat equals 3.40. It becomes fluid at a temperature of —252 degrees C. (—421 degrees F.), and solidifies at a temperature of —258 degrees C. (—432 degrees F.). Hydrogen is one of the chemical constituents of water, oxygen being the other constituent. Hydrogen burns with a pale blue non-luminous flame at high heat, the oxyhydrogen flame being used in autogenous welding and in flame-cutting processes. With air or oxygen, hydrogen forms a highly explosive mixture, especially in the proportion of two volumes of hydrogen to one volume of oxygen. It is, therefore, important to take care that free hydrogen does not mix mechanically with air or with free oxygen. Hydrogen is produced commercially as a by-product in the production of oxygen by the electrolytic method.

Hydrogen Brazing. See Brazing, Hydrogen Process.

Hydroline. Hydroline or "hydrolene," as it is sometimes called, is a trade name given to the petroleum pitch which remains after the cracking of petroleum oil. This pitch is usually graded as soft, medium, and hard, according to the melting point which ranges from 50 degrees centigrade to 150 degrees centigrade and higher.

Hydro-Metallurgical Process. This process, also known as *wet process*, is a method for obtaining a metal from its ore by dissolving the ore in a solution from which the metal can be precipitated. This method was developed for copper ores of low

grade containing only from $\frac{1}{4}$ to 1 per cent of copper. The copper obtained by the precipitation is known as *cement copper.*

Hydrometer. The hydrometer may be defined as an instrument for determining the density or specific gravity of a liquid. Special hydrometers are also used for other purposes. Classified in the broadest sense, there are two types of hydrometers; namely, hydrometers proper and hydrometers that are combined with thermometers, generally known as "thermohydrometers." Hydrometers proper may be divided into four specific classes: (1) Density hydrometers, which indicate the density of a liquid on a given scale. (2) Specific-gravity hydrometers, which indicate the specific gravity or relative density of a liquid as compared with water. (3) Per cent hydrometers, which indicate the percentage of a substance in a mixture or solution with water. (4) Arbitrary-scale hydrometers, which indicate the concentration or strength of a liquid on an arbitrarily defined scale. This latter class includes the well-known Baume type of hydrometer. The hydrometer consists of a glass tube having a weight at one end, so that it will float in a vertical position in the liquid the density of which is to be measured. The glass tube is provided with graduations on which the density is read off. When reading a hydrometer, the liquid is placed in a glass jar or cylinder, and the hydrometer carefully immersed in it to a point slightly below that to which it would sink by itself, and is then allowed to float freely. The reading should not be taken until the liquid and the hydrometer are fully at rest. The reading should be taken with the eye placed exactly in the plane of the surface of the liquid.

Hydro-Pneumatic Accumulator. This is a hydraulic accumulator in which the water within the cylinder compresses air which reacts upon it, thus serving as a substitute for the weights used in the ordinary type of accumulator. This type has been applied in connection with hydraulic elevators and presses.

Hydrostatic Joint. This is a type of joint used in large water mains, in which sheet lead is forced tightly into the bell of a pipe by means of the hydrostatic pressure of a liquid.

Hydrostatic Test. A hydrostatic test is a test to which tubing is sometimes subjected, consisting in subjecting it to an internal hydrostatic pressure.

Hygrometer. The hygrometer is an instrument for measuring the absolute or relative amount of moisture or humidity in the atmosphere. When the instrument is used only to determine changes in the humidity, it is termed a "hygroscope." The instrument depends usually upon the contraction or extension of certain substances when exposed to varying degrees of moisture.

The contraction of a substance with an increase in humidity, for example, can be recorded on a scale, and thus indicate the relative amount of moisture in the atmosphere.

Hyperbola. The hyperbola is a geometrical curve formed by a plane which intersects a cone parallel to the axis of the cone; hence it has two open branches, each extending to infinity, the principal characteristic of which is that the difference between the distances from any point on the hyperbola to two points on its major axis, known as *foci*, is constant.

Hyperbolic Logarithms. Hyperbolic, natural, or Napierian logarithms are used in many calculations, especially those involving the mean effective pressure in steam engine cylinders. The hyperbolic logarithms are usually designated "hyp. log." Sometimes hyperbolic logarithms are also designated "$\log_e$" and "Nap. log." To convert hyperbolic logarithms into common logarithms (having 10 for a base), multiply the hyperbolic logarithm by 0.43429. To convert a common logarithm to a hyperbolic logarithm, multiply the common logarithm by 2.30258. Hyperbolic logarithms are used extensively in higher mathematics.

Hyper-Eutectoid Steel. If the carbon content of steel exceeds about 0.90 per cent it will consist of pearlite plus free cementite and it is known as hyper-eutectoid. See Eutectoid Steels; also Steel, Constituents or Structure.

Hypocycloid. A hypocycloid is formed by the path of a point on the circumference of a circle which rolls on the inside of the periphery of another circle. This curve is used for part of the tooth shape of cycloidal gear teeth, part of the tooth shape being formed by an epicycloid, which is the curve formed by the path of a point on the circumference of a circle which rolls on the outside of the periphery of another circle.

Hypo-Eutectoid Steel. This is a steel which has a carbon content lower than about 0.90 per cent, and which is composed of ferrite and pearlite, the latter being an intimate mixture of ferrite (pure iron) and cementite (carbide of iron). See Eutectoid Steels; also Steel, Constituents or Structure.

Hypoid Gears. Hypoid gears are tapered gears with offset axes which, in general, look like spiral bevel gears. The tooth action of hypoid gears combines the rolling action of spiral bevel gears with a percentage of endwise sliding. The chief advantages of hypoid gears are noiseless operation, increased load-carrying capacity, the possibility of high reduction and low numbers of teeth, long life, and high efficiency. The axis of the pinion is offset from the axis of the gear by an amount that varies with the diameter and the ratio. The direction of offset determines

the hand of the spiral. In rear-axle design, a pinion below center will have a left-hand spiral, while a pinion above center will have a right-hand spiral. The position below center is preferable for two reasons: First, the axial thrust resulting on the pinion on a forward drive is directed away from the gear, and heavy loads tend to move the pinion out of mesh rather than draw it in; Second, the contact between mating tooth surfaces is more intimate on the drive side.

Tooth Loads: In computing the tooth loads of a pair of hypoid gears, the circumferential or tangential tooth load P of the gear at the center of the face may be determined from the known torque, and the pressure P_n or load normal to the tooth surface is then determined by dividing by the cosine of the normal pressure angle a and by the cosine of the spiral angle hg of the gear. Thus

$$P_n = \frac{P}{\cos a \times \cos hg}$$

This amount P_n is the total tooth load, or, in other words, the resultant of all components. It is noted that this total tooth load is only slightly larger than the effective circumferential or tangential tooth load P of the gear, for if we introduce as average amounts $a = 17\frac{1}{2}$ degrees and $hg = 8$ degrees, we obtain:

$P_n = 1.06\ P$ — an increase of 6 per cent.

In spiral bevel gears, the total tooth load P_n is considerably larger than the effective tangential tooth load. If a pressure angle of $17\frac{1}{2}$ degrees and a spiral angle of 35 degrees is assumed, the total load is as follows:

$P_n = 1.28\ P$ — an increase of 28 per cent, as compared with 6 per cent for hypoid gears.

Hysteresis. When the iron core of an electromagnet is magnetized by a current flowing first in one direction and then in the opposite direction, there is an energy loss known as hysteresis which take the form of heat. Thus after the iron has been magnetized by a current of electricity flowing in one direction, the iron will not, of itself, return to its normal condition, but requires additional energy to accomplish this, and, if a rapid reversal of magnetism takes place continuously, it will be found that a considerable amount of energy has been absorbed. The effect is especially noticeable in iron subjected to rapidly alternating magnetizing forces, as in generators and in transformers. It varies with the frequency and the 1.6th power of the intensity of induction. "Aging" is the term used for expressing the increase in hysteresis loss in core laminations of electrical machines from the continued magnetic reversals at comparatively

high temperatures during commercial operation. To prevent aging, silicon steel containing from 2.5 to 4 per cent of silicon is used. This steel has a much lower hysteresis loss than ordinary carbon steel. It is extensively used in transformer cores.

I

I-Beam. A name indicating the shape of one of the standard structural sections which is widely used in building construction and for many other kinds of structures. See Structural Shapes.

Idler Gear. An idler or intermediate gear simply transmits motion from one gear to another but it has no effect on the speed ratio, or the number of revolutions made by a driven shaft in a given time. This would also hold true if there were several intermediate gears. An idler, however, does change the direction in which the driven gear revolves. When driving and driven gears are located on fixed centers and when their sizes must be varied to obtain different speed ratios, an adjustable idler may be used as an intermediate transmitting member.

Idler Pulley. Some belt drives have an idler pulley bearing against one side of the belt to take up slack and also increase the arc of contact, especially on the smaller pulley. The idler of a Lenix or short-center belt drive is mounted on a pivoted weighted arm, and the belt, which is given plenty of slack, is automatically maintained at constant tension. This feature, in conjunction with the increased arc of contact, lengthens the life of the belt and greatly increases its driving power. Idler pulleys (also called "mule pulleys") are also used in conjunction with right-angle or other belt drives where the change in direction makes it necessary to support and guide the belt over pulleys.

Ignition Temperatures. The temperature of ignition is the degree of temperature at which a substance will combine with oxygen at a rate sufficiently rapid to produce a flame. The temperature of ignition has often been regarded as the temperature at which chemical combination begins, but this is not correct, because chemical combination has begun before a flame appears. The following temperatures are required to ignite the different substances specified: Phosphorus, transparent, 120 degrees F.; bisulphide of carbon, 300 degrees F.; guncotton, 430 degrees F.; nitroglycerin, 490 degrees F.; phosphorus, amorphous, 500 degrees F.; rifle powder, 550 degrees F.; charcoal, 660 degrees F.; dry pine wood, 800 degrees F.; dry oak wood, 900 degrees F.; illuminating gas, 1110 degrees F.; benzine, 780 degrees F.; petroleum, 715 degrees F.; gas oil, 660 degrees F.; machine oil, 715 degrees F.; coal tars, 930 degrees F.; and benzol, 970 degrees F.

Illium. Illium is an acid-resisting alloy of the following composition: Nickel, 60.65 per cent; chromium, 21.07 per cent; copper, 6.42 per cent; molybdenum, 4.67 per cent; tungsten, 2.13 per cent; aluminum, 1.09 per cent; silicon, 1.04 per cent; manganese, 0.98 per cent; and iron, 0.76 per cent. Carbon and boron are also present in small quantities. The melting point is about 2400 degrees F. The tensile strength of the cast metal is approximately 50,000 pounds per square inch.

Illium-R. A corrosion-resistant alloy from which strip, welded tubing, and cold-rolled rods are produced having, when work-hardened, a tensile strength ranging from 140,000 to 150,000 pounds per square inch. In an annealed condition, the tensile strength is from 95,000 to 105,000 pounds per square inch. Brinell hardness, work-hardened, from 340 to 365; annealed, from 175 to 240. The alloy is of approximately the same machinability as stainless steel. Strip stock of Illium-R is available in a number of widths and lengths and in gages from 8 to 34; adapted for drawing, perforating, stamping, and other fabrication methods. Rolled rod is suitable for tie-rods, light shafting, screw machine stock, and small hardware.

Immersion Brazing. This is a brazing process in which the work to be brazed is immersed in liquid spelter solder. It is also known as Dip Brazing.

Impact Extrusion. In this process, a slug of metal, either hot or cold, is placed in a cavity in a die having the size and shape of the required outside form of the part. A punch having the size and shape of the required inside form is then driven into the die, and the metal, having no other place to go, is squirted into the space between the punch and the die. This method has long been used for making toothpaste tubes and similar parts of soft metal. It is now being applied to steel, as in the case of artillery shells. See also Cold Extrusion.

Impact Tests. Materials are subjected to impact tests in order to determine their capacity to resist shocks. The *Charpy* and the *Izod* tests are both commonly employed. The same type of machine is used for these tests, but the test specimens differ. In making the test, a blow is delivered to the test specimen by a swinging pendulum and the energy required to fracture the specimen is indicated by a scale. The Charpy test specimen is a beam supported at both ends. The Izod specimen is a cantilever beam with support at one end only. Both specimens are 10 millimeters square and each contains a 45-degree notch. This notch is 2 millimeters deep and the bottom has a radius of 0.25 millimeter. The Charpy test specimen is 55 millimeters long and

the notch is in the center. One Izod specimen is 75 millimeters long and the notch is 28 millimeters from one end.

A well-known make of impact testing machine is equipped with a head on the pendulum which may readily be adjusted for either Charpy, Izod, or tension impact tests. When the head of the machine strikes the specimen, the energy is indicated on a scale by means of a pointer. There are two separate scales, one being for the Izod test and the other for the Charpy test. In the case of the tension impact test, either scale may be used. The tension impact test specimen is 6 millimeters in diameter and has enlarged threaded ends.

Torsion Impact Test: The torsion impact test breaks the specimen by twisting. This test is used chiefly for checking the toughness of hardened tool steels. The test specimen has a diameter of ¼ inch, and the enlarged ends may either be square or round with a flat on one side. In testing with one make of machine, a motor-driven momentum unit is rotated at a predetermined speed as indicated by a tachometer. By pushing a knob, the strikearm within the "bombproof" cover, is brought into the path of the hammers so that the specimen is suddenly fractured by the torsional impact. The residual speed is then read on the tachometer, and kinetic energies for various wheel speeds are shown by a table.

Impedance. Impedance is an abbreviated expression for a certain combination of the electrical properties of a circuit. For example, in a circuit containing resistance and reactance:

$$\text{Impedance} = \sqrt{\text{resistance}^2 + \text{reactance}^2}.$$

The impedance of a portion of an electric circuit to a completely specified periodic current and potential difference is the ratio of the effective value of the potential difference between the terminals to the effective value of the current, there being no source of electromotive force in the portion under consideration.

Impeller. In a centrifugal pump, the impeller is the rotating element provided with vanes, which draws in air or liquid at the center and expels it at a high velocity at the periphery. There are two impellers in a rotary blower running in mesh with each other.

Imperial Bushel. One British Imperial bushel equals 8 Imperial gallons, equals 1.2837 cubic feet.

Imperial Gallon. This is a legal measure of capacity in Great Britain, and is defined as the volume of ten pounds of pure water at 62 degrees F., and equal to one-eighth of an Imperial bushel. The volume of the Imperial gallon equals 277.42 cubic inches, or approximately 1.2009 U. S. gallons.

Imperial Wire Gage. The Imperial wire gage is the standard British wire gage authorized by Order in Council, August 23, 1883, as the legal standard for Great Britain. It is also known as the "Standard wire gage" (abbreviated S.W.G.), as the "New British Standard wire gage" (abbreviated N.B.S.) and as the "British Legal Standard wire gage."

Incandescent Lamps. The incandescent lamp is based upon the principle that, when an electric current is sent through a conductor of high resistance, the conductor is heated. If the material for the conductor, the current, the voltage, and other conditions are such that the conductor will be heated until it becomes incandescent and, hence, gives out light, this combination embodies the principle of the electric incandescent lamp. Carbon-filament lamps have been superseded largely by tungsten-filament lamps which are more efficient. Usually these filaments operate in a glass bulb which has a high vacuum or which is filled with a mixture of argon and nitrogen. This serves to increase the life of the filament which would soon burn out if exposed to oxygen. Incandescent lamps may be operated on either direct-current or alternating-current circuits, and either in multiple or series.

Operation of an incandescent lamp at voltage 10 per cent higher than rated may decrease its life by as much as 70 per cent, while operation at a voltage of 10 per cent lower than rated may decrease the light output by as much as 30 per cent. For most satisfactory results, the applied voltage should be maintained within 3 per cent of that rated for the lamp.

Inch. A unit of length measurement; 1 inch = 2.54 centimeters = 25.4 millimeters.

Inch, Circular. See Circular Inch.

Inch-Pound. Torsional tests are made to ascertain the elastic limit and the ultimate torsional strength. Since the strain varies over the sectional area, it is not possible to express the torsional strain as "pounds per square inch," but as "pound-inches" or "inch-pounds." The torsional or twisting moment in pound-inches is obtained by multiplying the pull applied by the lever arm through which it acts. For instance, assume that a wrench were gripped on a pipe; then, if a pull of 100 pounds is exerted on the wrench at a distance of 10 inches from the center of the pipe, the torsional strain on the pipe would be $10 \times 100 = 1000$ pound-inches. See also Pound-foot.

Inclinable Power Presses. Presses of the inclinable class are so designated from the fact that the upper part of the frame may be inclined to allow finished parts to slide from the die due to the

action of gravity. This type of press may also be used with the inclinable member in the vertical position. Inclinable power presses are generally of the gap type. They are extensively used and are particularly adapted for blanking, piercing, forming, and shallow drawing operations on household utensils, small automobile parts, and many other articles, as well as light embossing operations on jewelry, etc. Presses of this type are generally built in sizes having capacities ranging from two to seventy-five tons. A press of greater capacity than the maximum mentioned would be so heavy as to be difficult to incline by means of the hand-operated mechanism with which these presses are usually furnished.

The inclinable power press is particularly suitable for the automatic production of small parts when it is equipped with a feeding arrangement adapted to the part being produced. For the first operation on a given part the stock is usually fed to the dies in the form of a ribbon or strip by either a single- or a double-roll feed. Very high production rates can be obtained in this manner, it being frequently possible to produce completed or partly completed parts as the rate of 150 per minute. Other styles of feeds used for succeeding operations include dial, hopper, and finger mechanisms. *Inclined presses* have the frame built in a fixed, inclined position, and are thus non-adjustable.

Inclined Plane. A plane which makes an oblique angle with the horizontal and which is used to facilitate the moving of bodies, as in the case of a wedge, is classed as one of the "mechanical powers." If μ = coefficient of friction; a = angle of plane, W = weight of body to be moved along plane, and F = force required to move body; then if F acts parallel to the inclined plane and so as to pull the body upward, $F = W\ (\mu \cos a + \sin a)$. If the movement of the body is down the plane, then $F = W\ (\mu \cos a - \sin a)$. If the force acts parallel to the base of the plane, then $F = W \tan (a + \theta)$. The coefficient of friction $= \tan \theta$.

Inconel. Inconel and Inconel "X" are trade names for nickel-chromium-iron alloys (the latter also contains titanium) that exhibit high-strength, corrosion-resistant properties especially at high temperatures.

Independent Chucks. Independent chucks usually have four radial jaws which are fitted in grooves or slots in the chuck body and are adjusted independently by means of screws that are turned by a chuck wrench.

Independent Crane. An independent crane is a jib crane the post of which is so pivoted in the floor foundation and at the top that it is free to make a complete circle about its pivots. This

crane is suitable for use in the center of large bays in shops and foundries, as it can serve a wide area.

Indexing. The process of dividing a circular part into equal spaces or divisions by means of an indexing- or dividing-head is known as indexing. There are three systems of indexing known as the plain or simple system, the compound system, and the differential system.

Plain Indexing: When indexing, if the required division or movement can be obtained by simply turning the index-crank of the indexing or dividing-head the required amount, and engaging it with one of the holes in the index plate, this is known as *plain* or *simple* indexing, because only one indexing movement is necessary, instead of two movements, as with compound indexing.

Compound Indexing: Ordinarily, the index-crank of a dividing-head must be rotated a fractional part of a revolution, when indexing, even if one or more complete turns are required. This fractional part of a turn is measured by moving the latch-pin a certain number of holes in one of the index circles; but, occasionally, none of the index plates furnished with the machine has circles of holes containing the necessary number for obtaining a certain division. One method of indexing for divisions which are beyond the range of those secured by the plain or simple method is to first turn the crank a definite amount in the regular way, and then the index plate itself, in order to locate the crank in the proper position. This is known as *compound* indexing, because there are two separate movements which are, in reality, two simple indexing operations. The index plate is normally kept from turning by a stationary stop-pin at the rear, which engages one of the index holes. When this stop-pin is withdrawn, the index plate can be turned.

Differential Indexing: This system is the same in principle as compound indexing, but differs from the latter in that the index plate is rotated by suitable gearing which connects it to the dividing-head spindle. This rotation or differential motion of the index plate takes place when the crank is turned, the plate moving either in the same direction as the crank or opposite to it, as may be required. The result is that the *actual* movement of the crank, at every indexing, is either greater or less than its movement with relation to the index plate. This method of turning the index plate by gearing instead of by hand makes it possible to obtain any division liable to arise in practice, by using one circle of holes and simply turning the index crank in one direction, the same as for plain indexing. In actual practice, the number of turns of the index-crank for obtaining different divisions is usually determined by referring to indexing tables.

Indexing Attachments. Attachments of this general type are used on milling machines whenever equally spaced grooves must be milled in such parts as cutters, reamers, gears, ratchets, etc. The indexing attachment is designed to hold the work and rotate it whatever fractional part of a turn is likely to be required. Attachments used for indexing may also be designed to rotate the work slowly and continuously in conjunction with the table-feeding movement for milling helical grooves in reamers, gears, etc. Several different names have been applied to indexing attachments, such, for example, as *index centers*, index or *indexing head, dividing head,* and *spiral head* when the attachment is designed both for indexing and helical or spiral milling.

The name index centers is based upon the fact that parts to be indexed usually are held between the centers of an index head and a foot-stock. The term *plain index centers* has been applied to a simple attachment designed merely for indexing or dividing. When there is angular adjustment of the index-head spindle, the term *universal index centers* may be used to distinguish such an attachment from the plain type which does not have the angular adjustment. The name *universal spiral index centers* is applied by at least one manufacturer to the type which may be used not only for indexing, but for rotating the work in helical milling. Such indexing attachments may also be known as dividing heads or as indexing heads.

Optical Dividing Head: The main feature of the optical dividing head is the means provided to insure accurate settings. There is a glass dial mounted directly on the spindle, and this dial is graduated to 360 degrees around the periphery. While indexing the spindle, the dial graduations may be observed through a microscope as the hand-wheel is being turned, and when the desired setting has been obtained, the spindle is locked in place. Readings are made directly in minutes. The spaces between the degree graduations of the glass dial are magnified sixty times by the microscopic eye-piece, and appear about 1¾ inches apart. A second vernier scale of 60 minutes is projected by the ocular into the field of observation, and, as the graduations on this scale appear about 0.03 inch apart, it is safe to estimate settings within 20 seconds.

Indexing, Block. See Block Indexing.

Indian Corundum. This is a natural abrasive obtained from India, which contains about 73 per cent of crystalline alumina, which constitutes the cutting material of the abrasive. As an abrasive, it is better than emery, but is not as good as the Canadian or Georgia abrasive.

Indian Steel. See Damascus Steel.

Indicated Horsepower. The actual power exerted by the expanding steam in the cylinder of a steam engine, or the power of the explosion and expansion of the gases in the cylinder of a gas or oil engine, is known as the *indicated* horsepower. The indicated horsepower does not take account of any frictional losses; hence, it is always greater than the brake horsepower. Indicated horsepower is so named because the amount of power developed in the cylinder per stroke is determined by getting the mean effective or average pressure throughout the stroke, from an indicator diagram obtained with an engine indicator. See also Horsepower.

Indicator Diagrams. A diagram may be made to represent graphically the work done in an engine cylinder during one stroke of the piston. An indicator is a device for making a diagram of what actually takes place in an engine cylinder under working conditions. Such a diagram taken from a steam engine cylinder. shows the points of admission, cut-off, and release, and indicates accurately the pressures acting on both sides of the piston at all points of the stroke. The indicator diagram provides means of determining the mean effective pressure, from which the indicated horsepower of the engine can be determined. Such diagrams, taken from engines in service, also show any defects in steam distribution due to improper valve setting. Just how an indicator diagram represents the work done in an engine cylinder will be apparent by considering first the ideal or "work diagram."

Work Diagram: One of the first steps in the design of a steam engine is the construction of an ideal diagram, and the engine is planned to produce this as nearly as possible when in operation. First assume the initial pressure, the ratio of expansion, and the percentage of clearance, for the type of engine under consideration. Draw lines OX and OY at right angles. (See Fig. 1.) Make OR the same percentage of the stroke that the clearance is of the piston displacement; make RX equal to the length of the stroke (on a reduced scale). Erect the perpendicular RA of such a height that it shall represent, to scale, an absolute pressure per square inch equal to 0.95 of the boiler pressure. Draw in the dotted lines AK and KX, and the atmospheric line LH at a height above OX to represent 14.7 pounds per square inch. Locate the point of cut-off, B, according to the assumed ratio of expansion. Points on the expansion curve BC are found as follows: Divide the distance BK into any number of equal spaces, as shown by a, b, c, d, etc., and connect them with the point O. Through the points of intersection with BP, as a', b', c', d', etc., draw horizontal lines, and through a, b, c, d, etc., draw vertical lines. The intersection of corresponding horizontal and vertical lines will be points on the theoretical expansion line. If the engine is to

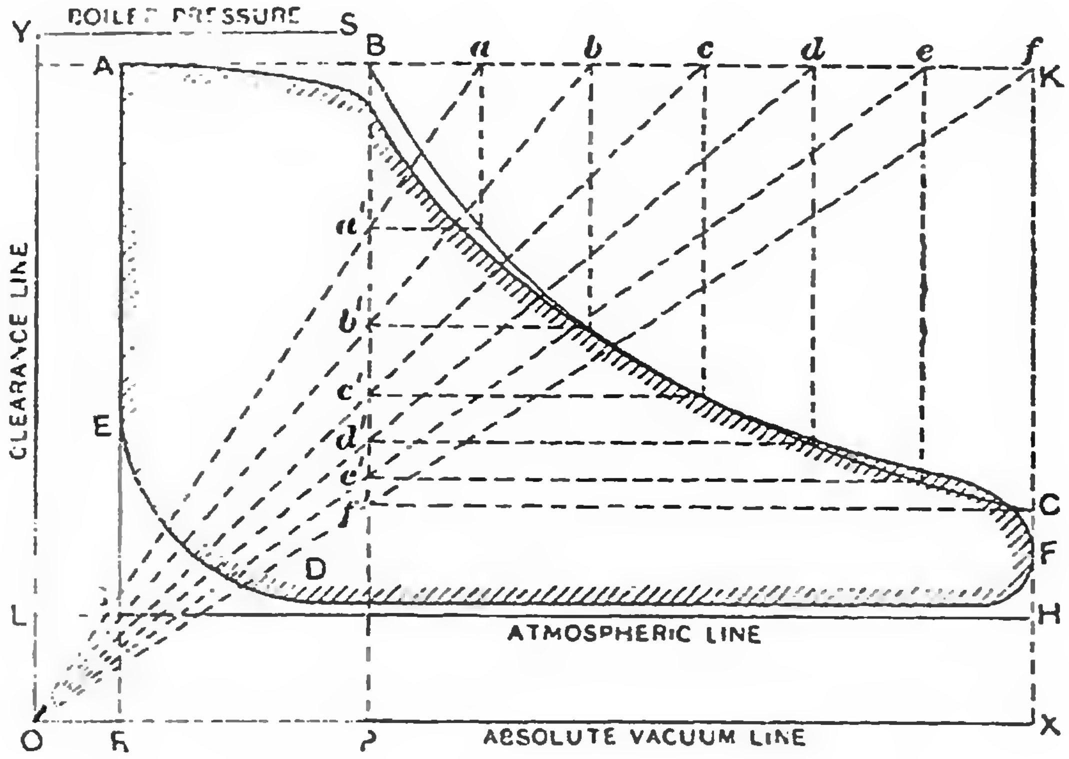


Fig. 1. Construction of a Steam Engine Work Diagram

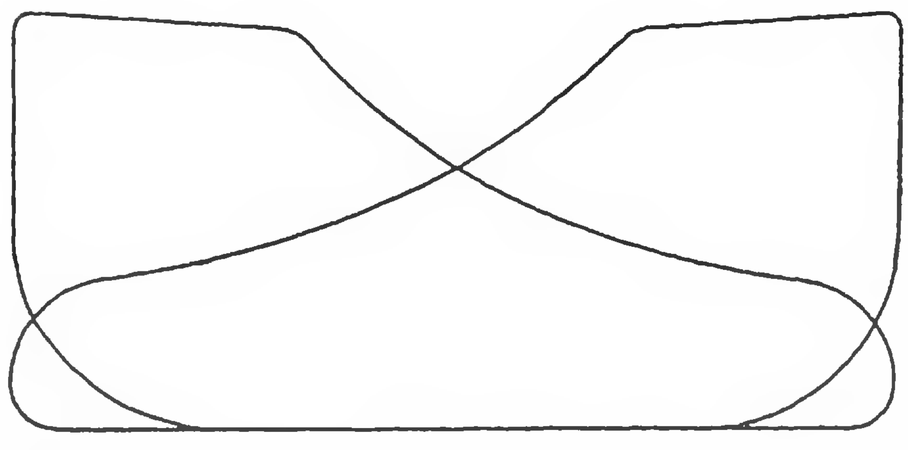


Fig. 2. Typical Indicator Diagrams

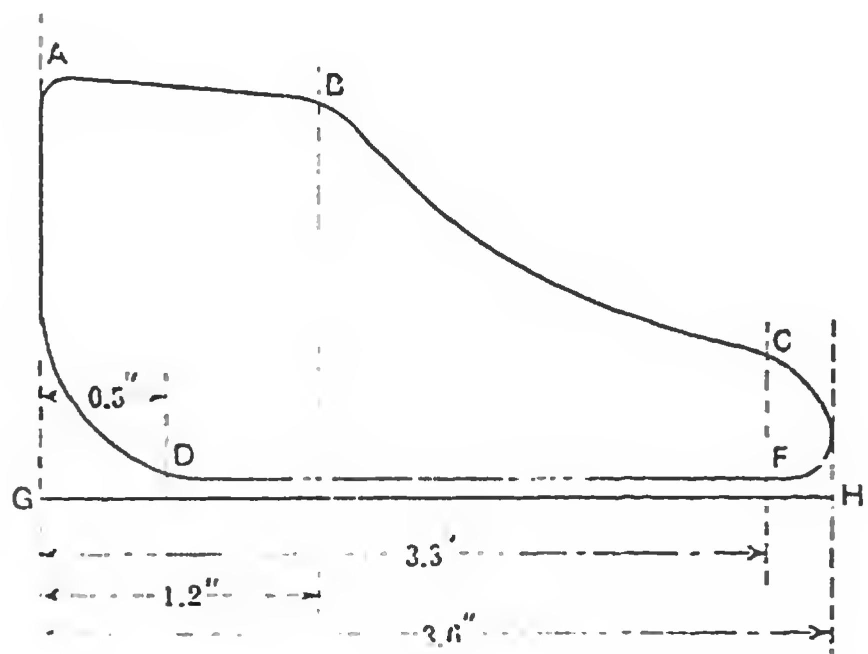


Fig. 3. Diagram for Illustrating Method of Computing Cut-off, Compression and Mean Pressure

be non-condensing, the theoretical work, or indicator diagram, as it is called, will be bounded by the lines *ABC HG*.

Indicator Diagram: The actual diagram obtained with an engine indicator, will vary somewhat from the theoretical, as shown by the shaded lines. The admission line between *A* and *B* (Fig. 1) will slant downward slightly, and the point of cut-off will be rounded, owing to the slow closing of the valve. The first half of the expansion line will fall below the theoretical, owing to a drop in pressure caused by cylinder condensation, but the actual line will rise above the theoretical in the latter part of the stroke on account of reevaporation, due to heat given out by the hot cylinder walls to the low-pressure steam. Instead of the pressure dropping abruptly at *C*, release takes place just before the end of the stroke, and the diagram is rounded at *CF* instead of having sharp corners. The back pressure line *FD* is drawn slightly above the atmospheric line, a distance to represent about 2 pounds per square inch. At *D* the exhaust valve closes and compression begins, rounding the bottom of the diagram up to *E*. The area of the actual diagram, as outlined by the shaded lines, will be smaller than the theoretical, in about the following ratio: Large medium-speed engines, 0.90 of theoretical area; small medium-speed engines, 0.85 of theoretical area; high-speed engines, 0.75 of theoretical area. Diagrams for both ends of the engine cylinder are usually on one card as shown by Fig. 2. It is simpler to take them both on the same card, and also easier to compare the working of the two ends of the cylinder. The analysis of a card for practical purposes is shown in Fig. 3. Suppose, for example, that the length of the diagram measures 3.6 inches; the distance to the point of cut-off is 1.2 inches; and the distance to the point of release is 3.3 inches. Then, by dividing 1.2 by 3.6, the cut-off is found to occur at $1.2 \div 3.6 = 1/3$ of the stroke. Release occurs at $3.3 \div 3.6 = 0.92$ of the stroke. Compression begins at $(3.6 - 0.5) \div 3.6 = 0.86$ of the stroke. The diagrams shown in Figs. 2 and 3 are from non-condensing engines, and the back-pressure line is, therefore, above the atmospheric line, as indicated.

Mean Effective Pressure: The method of determining the mean effective pressure is as follows: First measure the area of the card in square inches, by means of a planimeter, and divide this area by the length in inches. This gives the mean ordinate; the mean ordinate, in turn, multiplied by the strength of the spring used, will give the mean effective pressure in pounds per square inch. For example, suppose that the card shown in Fig. 3 is taken with an indicator having a 60-pound spring, and that the area, as measured by a planimeter, is found to be 2.6 square inches. Dividing the area by the length gives $2.6 \div 3.6 =$

0.722 inch as the mean ordinate, and this multiplied by the strength of spring gives a mean effective pressure of $0.722 \times 60 = 43.3$ pounds per square inch.

In practice, diagrams taken from the two ends of the cylinder usually vary more or less, due to inequalities in the valve action. Again, the effective area of the piston on the crank end is less than that on the head end, by an amount equal to the area of the piston-rod. For these reasons, it is customary to compute the mean effective pressure of all the cards separately, and take, for use in the horsepower formula, the average of the various computations.

Indicator Diagram from Air Compressor: Fig. 4 represents a typical indicator card from an air compressor cylinder; MN is the atmospheric pressure line; the piston displacement is denoted by V and the clearance volume by V_c. During the suction stroke, air is drawn into the cylinder along the suction line DC. The pressure p_s inside the cylinder during the suction stroke must necessarily be less than the atmospheric pressure, or there would be no flow of air into the cylinder. At C the cylinder is full of air at pressure p_s, and the piston on its return stroke compresses this air along line CB. At point B the discharge valves open and the volume of high-pressure air in the cylinder is driven out

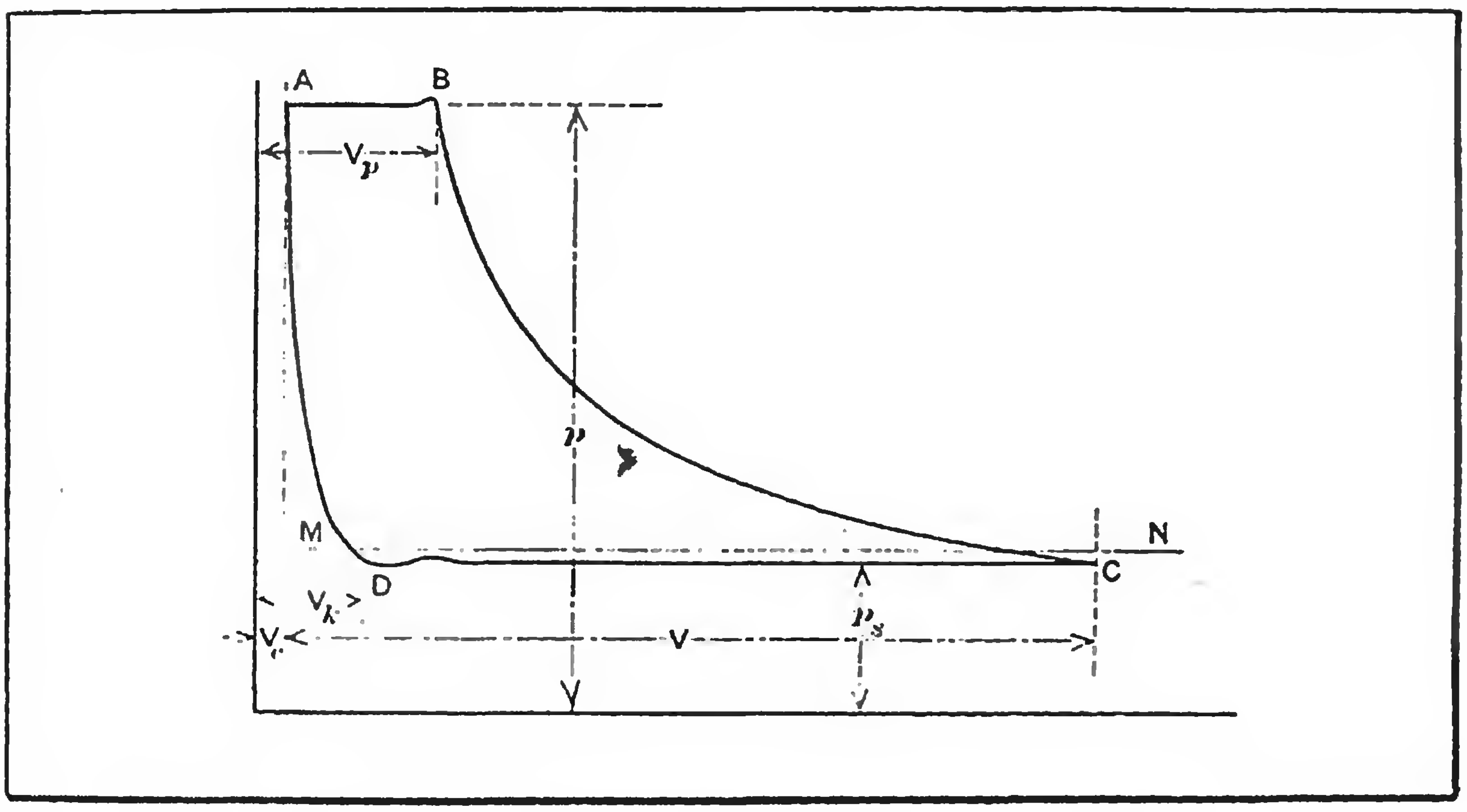


Fig. 4. Typical Air Compressor Diagram

along the line BA until at the end of the stroke, at A, only the clearance volume, V_c, is filled with air at the pressure p. On the suction stroke, no air can be drawn into the cylinder until this clearance air has expanded so that its pressure drops to p_s, less than atmospheric pressure, thus allowing the suction valves to open. For simplicity, the slight additional drop in pressure indi-

cated by the wavy line at D, necessary to overcome the inertia of the suction valves, is disregarded.

The assumption that the volume of free air drawn into the compressor per minute is equal to the piston displacement could only be true in a cylinder having no clearance volume, and also where the temperature and pressure of the air on the suction side of the piston are the same as the temperature and pressure of the atmosphere.

In order to cause a flow of air into the suction end of the cylinder, the pressure p_s must be less than atmospheric pressure, as previously mentioned; therefore, the air expands as its pressure drops in entering the cylinder, and the original volume of the free air drawn in is less than the volume occupied by this air after it is in the cylinder. Furthermore, the temperature of the air inside the suction end of the cylinder is higher than the atmospheric temperature, since the air is heated as it enters, by contact with the walls of the cylinder left warm by the previous compression stroke. This also causes expansion and still further diminishes the volume of outside air required to fill the suction space.

Indium. A rare metallic chemical element (symbol In) found combined in small quantities in many ores, especially zinc blende. It is a soft, ductile metal with a "whiter" color than tin and the atomic weight is 114.76. Indium has a melting point of 155 degrees C. and is not easily oxidized. It has found application as a plating for bearings in airplane motors as it has great corrosion resistance, particularly against lubricants and acids. When so used indium is first electroplated on a base of cadmium, silver and copper and is then diffused into this base by heating.

Induced Draft. The induced draft system of a power plant has a fan placed between the furnace and the chimney, and the air is drawn through the furnace by suction. This corresponds with the natural draft produced by a chimney, and also permits of the use of an economizer in the main smoke connection. With this arrangement, all leakage is inward and there is no danger of dust and smoke being blown into the fire-room, as with forced draft. On the other hand, a system of induced draft is more expensive to install, because the gases, being at a higher temperature, have a greater volume, and require a higher speed and more power to move them.

Inductance. The term *inductance* is used to denote the property of an electric circuit (or circuit element such as a coil), or of two neighboring circuits (or circuit elements), which determines the electromotive force induced in one of the circuits or elements by a change of current in either of them. The unit of inductance is the *henry*.

Inductance Unit. See Henry.

Induction. Induction, in electricity, is the phenomenon by which a body charged with electricity or magnetism, or conducting an electric current, produces an electric or magnetic condition in a neighboring body without direct contact. "Electrostatic induction" is the production of an electrical charge in a body by the influence of another body which is charged with static electricity. "Electrodynamic induction" is the production of an electromotive force in another circuit by the influence of a change in electric current. When the current is induced by the action of a magnet, or when a magnetic condition is induced by an electric current, the phenomenon is known as "electro-magnetic induction." "Magnetic induction" is the production of a magnetic condition in a magnetic substance by another magnet.

Induction Clutch. The induction clutch is similar in its operation to an induction motor. The induction clutch transmits power without contact between its driving and driven members.

Induction Coil. An induction coil, sometimes called a spark coil, is a device which is used to obtain a high alternating electromotive force from a low direct electromotive force. There are two types: The primary or single-coil type and the secondary or two-coil type, sometimes called *Ruhmkorff coil.* In the primary type, the coil is wound around a soft iron core and some form of interrupter and battery are placed in series with it. Every time the circuit is interrupted, the rapid decrease in current flow causes a high induced electromotive force which causes a spark to jump across the open contacts of the interrupter. This type of coil was at one time used for gasoline engine ignition, with the make and break unit located inside the cylinder. Since it is not suitable for high-compression engines or for operation at high speed, it has been replaced by the secondary type.

In the secondary type, two coils are used which are generally wound on a silicon-steel core. The primary winding consists of a relatively small number of turns and this winding is placed in series with the source of power which, when used for gasoline engine ignition, is usually a storage battery connected in parallel with a charging generator, and also in series with a circuit interrupter. The secondary is made up of a large number of turns of wire and is connected with the distributor and the various spark plugs. Here, again, interruption of the direct current in the primary coil induces a high voltage which is stepped up by transformer action in the secondary and causes a flow of current across the various spark plug gaps as they are connected sequentially in the circuit by the distributor.

Induction Hardening. See Tocco Hardening Process.

Induction Motors, Polyphase. Commercial induction motors have a stationary element called the "stator," and a rotating element called the "rotor." The induction motor derives its name from the fact that the secondary member or rotor receives its electrical energy from the primary member or stator by magnetic induction, there being no electrical connection between the stator and rotor windings. The transformer is the most commonly known piece of electrical apparatus, in which one winding receives its electrical energy from a second and independent winding by magnetic induction; hence, it is common practice to consider an induction motor as a transformer with a stationary primary and a revolving secondary. Thus, the stator is often called the "primary," and the rotor, the "secondary." The windings are so placed in the stator slots as to cause a rotating magnetic field to be produced when alternating current is supplied. The rotor of an electric induction motor must revolve at a speed somewhat lower than synchronous, in order that a secondary current and a torque shall be created. The actual speed of an induction motor is, therefore, less than the synchronous speed by a few per cent, called the "per cent slip." The slip increases with the load, thus increasing, by the cutting of lines of force, the current in both secondary and primary windings, and the torque.

Squirrel-Cage Induction Motors: This is the simplest type of induction motor and is most commonly used for constant-speed, general-purpose work. A series of copper or aluminum bars fitted into slots in the rotor core and rigidly connected at each end to a continuous ring constitutes the "squirrel-cage" rotor winding from which the motor takes its name.

Wound-Rotor Induction Motors: This type of induction motor is used where starting must be accomplished under extremely heavy loads or where smooth speed acceleration is needed as in hoists, cranes, or conveyors. In addition to a squirrel-cage winding, a number of form-wound coils are used as an auxiliary rotor winding, and these are connected to three collector rings. The currents induced in this winding, when the motor is connected to the line, pass through brushes bearing on these rings to an external variable-resistance control which governs starting and running speeds.

High-Frequency Induction Motors: This type of induction motor is of the same general construction as the standard squirrel-cage motor but is designed to operate at higher frequencies. A speed of 3600 revolutions per minute is the maximum that can be obtained with ordinary 60-cycle motors. These high frequency motors are, on the other hand, high-speed motors with speeds ranging, ordinarily, from 3600 to 18,000 revolutions per minute. Still higher speeds are feasible.

The established frequency and voltage ranges for which they are designed are:

1. Normal-frequency series with a frequency range from 60 cycles at 220 volts to 100 cycles at 367 volts maximum.
2. First high-frequency series with a frequency range of 120 cycles at 220 volts up to 199 cycles at 367 volts, or down to 60 cycles at 110 volts. Or 120 cycles at 440 volts up to 150 cycles at 550 volts or down to 60 cycles at 220 volts.
3. Second high-frequency series with a frequency range of 200 cycles at 110 volts up to 540 cycles at 297 volts or down to 180 cycles at 99 volts.
4. Portable-hand-tool series with frequencies of 175 or 180 cycles.

The development of the high-speed induction motor for direct application to machine tools has been of great importance to the machine tool industry. Moderate and high-speed motors are now applied to the same machine, the high-speed motor generally being used to drive the cutting tool, and the slower speed motor to drive the feeding mechanism.

Induction Motors, Single Phase. See Single Phase Motors.

Induction Pipe. The name "induction pipe" is sometimes given to the pipe through which the live steam passes to the steam chest of a steam engine. The opening from the steam chest into the cylinder through which the live steam flows is known as the *induction port.* The *induction valve* is the valve controlling the supply of live steam to the cylinder.

Induction Regulator. An induction regulator is a form of transformer, the secondary voltage of which may be varied from maximum to zero and then to maximum in the opposite direction, by changing the relative angular position of the primary and secondary. The induction regulator is used to maintain constant voltage on circuits where constant voltage is important, such as lighting circuits, the varying load of which makes such a device necessary. A small variation in the voltage of a lighting circuit makes a large variation in the luminosity of the lamps, and close regulation is important. The primary is connected across the line and the secondary is connected in series with the line. This type of regulator gives a perfectly smooth change without steps.

Inertia, Moment of. See Moment of Inertia; also Polar Moment of Inertia.

IngOclad. A material consisting of a sheet of mild carbon steel with a thin sheet of stainless steel welded to it. Combines the non-corrosive properties of stainless steel with the low cost of carbon steel. Used for cooking utensils, shower-bath compartments, beer barrels, milk storage tanks, etc.

Ingots. After a large body of steel has been refined in an open-hearth furnace or Bessemer converter, it is common practice to pour the molten steel into cast-iron molds thus forming ingots of convenient size for subsequent rolling or forging operations.

In *bottom-pouring* an ingot, the metal is poured into a vertical runner and flows up into the mold through an opening in the bottom. As the runner is kept full of metal by the constant flow from the ladle, the level in the ingot mold gradually rises. While all metallurgists and steel makers do not agree that bottom-poured ingots possess the superior qualities which others claim for them, the principal advantages from this method of pouring may be summarized as follows: The metal flows up into the mold very quietly and without any splashing such as occurs when pouring from the top and especially when first beginning to pour into the bottom of the mold. This splashing action which accompanies top-pouring results in a poor surface condition of the ingot. It is also claimed that when pouring from the bottom there is less tendency to entrap dirt or foreign matter in the ingot, as this is carried outward to the surface of the mold when the metal flows up through the opening in the center. Still another advantage claimed for the bottom method of pouring is that there is practically no oxidizing action of the air upon the stream of metal which flows from the ladle. The distance between the bottom of the ladle and the top of the runner is only a few inches, so that there is no time for oxidizing action to occur, which is not the case when the metal is poured from the top and there is a long stream extending from the ladle to the level of the metal in the ingot. Some metallurgists contend that the advantages which might accrue from bottom-pouring are partially, if not entirely, offset by a slagging off of the refractory lining in the runner; others claim that such slagging action can be reduced until it is negligible.

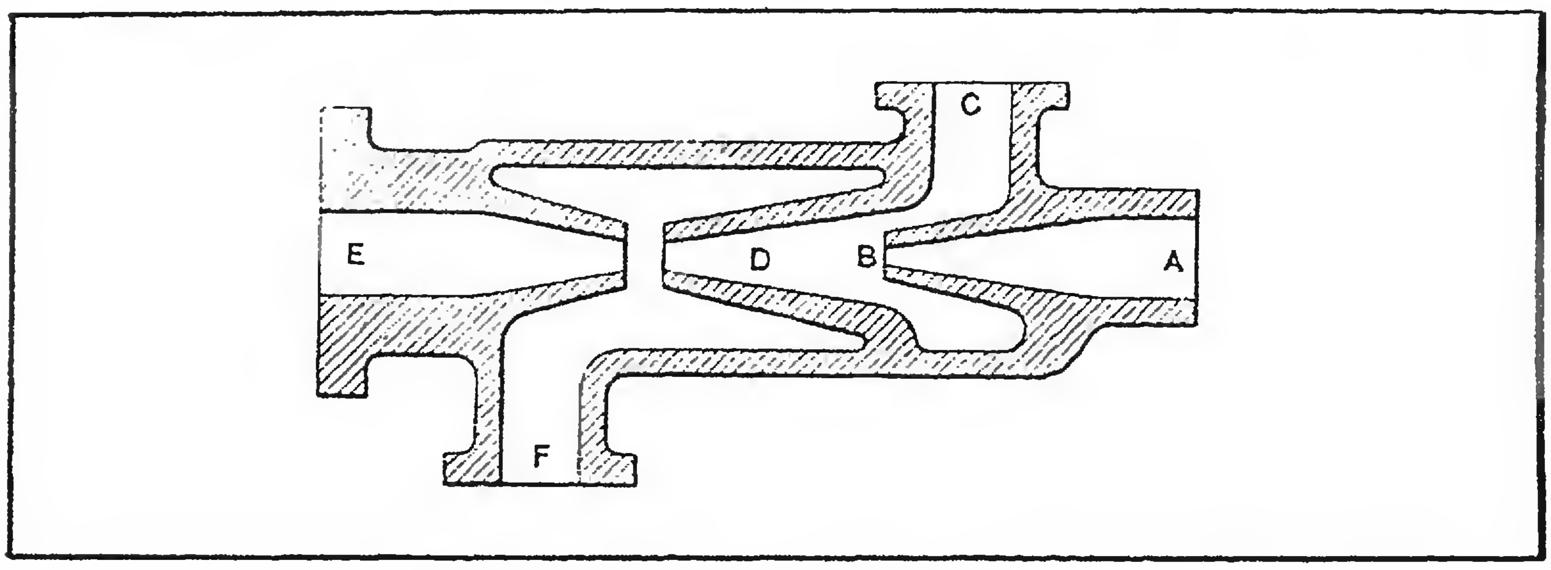
Inhibitors. In the pickling of steel in sulphuric acid, the steel itself is attacked after the scale is removed. To prevent or to reduce this attack to a minimum, a class of addition agents has been developed that are called "inhibitors." The inhibitor covers the steel after the scale has been removed and prevents a further attack of the base metal by the acid.

Initial Pressure. The pressure in the cylinder of a steam engine up to the point of cut-off, is called the initial pressure. It is usually slightly less than boiler pressure owing to "wire-drawing" in the steam pipe and ports.

In air compressors the initial pressure is the pressure from which the air is compressed to a higher pressure. The initial pressure is usually the atmospheric pressure.

Initial Volume. In air compression, the initial volume is the volume of the air before it has been compressed. This is usually the volume of the air at atmospheric pressure.

Injector. The injector is a device for feeding water to steam boilers, the steam of the boiler itself being used to force water into the boiler against its own pressure. The diagram shows the elementary principle of the action of an injector. The steam from the boiler enters at *A* and passes through the orifice *B;* the feed water enters through *C* into a chamber which entirely surrounds the steam nozzle. When the stream strikes the feed water, it is condensed, and a vacuum is produced in the chamber *D;* hence, the water is forced with great velocity into and through this chamber, its velocity being increased by the pressure of the steam entering at *B*. When the water expands in the lower part of the nozzle at *E,* it loses velocity, but, according to the laws of hydrodynamics, it gains in pressure, so that it can enter the boiler through a check-valve. The pipe at *F* is an overflow, providing an outlet for the steam and water until the velocity and pressure acquired is great enough to force the water into the boiler.



Principle of Injector Action

Inspection Gages. Inspection gages are used by the inspector for checking the product. These gages are generally of the same design as the working gages, except that they have a smaller allowance for wear. See Gage Classification.

Inspirator. The inspirator is a device consisting of two combined injectors or a double injector used in connection with a steam boiler. One injector is used for raising the feed water for the boiler from a reservoir and delivering it to the other injector, which forces it into the boiler.

Instrument Metal. For certain classes of scientific and other instruments, it is important to use a metal which has a very small coefficient of expansion. A nickel steel alloy known as Invar is adapted to work of this kind. See Invar; also Platinite.

Instrument Threads. The standard instrument thread employed by the Royal Microscopical Society of London, England (sometimes known as the "Society" thread), is used for microscope objectives and the nose-pieces of the microscope into which these objectives screw. The form of the thread is the standard Whitworth form. The number of threads per inch is 36. There is one size only. The maximum pitch diameter of the objective is 0.7804 inch and the minimum pitch diameter of the nose-piece is 0.7822 inch. The Royal Photographic Society Standard Screw Thread ranges from 1-inch diameter upward. For screws less than 1 inch, the Microscopical Society Standard is used. The British Association thread is another thread system employed on instruments abroad.

Insulation, Heat. The best insulating materials for preventing loss of heat in steam or hot water pipes are those that hold air confined in minute cells. Incombustible mineral substances are to be preferred to combustible material. No covering should be less than one inch in thickness. Mineral wool, a fibrous material made from blast furnace slag, is an excellent non-combustible covering, but it is brittle and, therefore, likely to be reduced to a powder when subjected to vibration. The percentage of steam lost through a covering of mineral wool about 1¼ inches thick is about one-tenth of that lost from bare pipes. A heat insulation composed of a number of layers of asbestos paper in which are imbedded small pieces of sponge is also very effective. The amount of heat lost with the general commercial pipe coverings is from one-eighth to one-sixth of the amount that would be lost with bare pipes. In most cases, it pays to use the best commercial pipe covering obtainable, because often the material is paid for many times over during the first year by the saving effected by its use. Few steam lines at the present time are provided with a covering thick enough for the greatest net saving. However, where fuel is cheap and the lines are in use only a small percentage of the time, the thinner coverings have their advantages. Also, there are places, as on some heating systems, where the heat lost through the coverings is not wasted. Therefore, a careful study of conditions is necessary before a certain type of covering can be recommended. The durability of materials used for pipe coverings is also an important factor in determining the most economical covering for a given set of conditions. The proper basis for comparing costs is the cost per year and not the first cost of the material.

Insulation, Thermal Classification. For purposes of assigning definite permissible temperature limits to the insulation in motors and generators, and other electrical equipment, according to the material used therein, the following classification has

been established as an American Institute of Electrical Engineers Standard.

Class O insulation consists of cotton, silk, paper, and similar organic materials when neither impregnated nor immersed in a liquid dielectric.

Class A insulation consists of (1) cotton, silk, paper, and similar organic materials when either impregnated or immersed in a liquid dielectric; (2) molded and laminated materials with cellulose filler, phenolic resins and other résins of similar properties; (3) films and sheets of cellulose acetate and other cellulose derivatives of similar properties; and (4) varnishes (enamel) as applied to conductors.

Class B insulation consists of mica, asbestos, fiber glass and similar inorganic materials in built-up form with organic binding substances. A small proportion of Class A materials may be used for structural purposes only.

Class C insulation consists entirely of mica, porcelain, glass, quartz and similar inorganic materials.

As used in the Class A definition, an insulation is considered to be "impregnated" when a suitable substance replaces the air between its fibers, even if this substance does not completely fill the spaces between the insulated conductors. The impregnating substances in order to be considered suitable, must have good insulating properties; must entirely cover the fibers and render them adherent to each other and to the conductor; must not produce interstices within itself as a consequence of evaporation of the solvent or through any other cause; must not flow during the operation of the machine at full working load or at the temperature limit specified; and must not unduly deteriorate under prolonged action of heat.

The electrical and mechanical properties of the insulated winding must not be impaired by application of the temperature permitted for Class B material. (The word "impair" is here used in the sense of causing any change which could disqualify the insulating material for continuous service.) The temperature endurance of different Class B insulation assemblies varies over a considerable range, in accordance with the percentage of Class A materials employed, and the degree of dependence placed on the organic binder for maintaining the structural integrity of the insulation.

Insulators, Electrical. Materials whose electrical conductivity is so low that the flow of current through them can usually be neglected under ordinary conditions are known as insulators and comprise a large number of natural and synthetic substances, varying widely in composition and physical properties. In some instances, insulating materials are required which are highly

heat-resistant or arc-proof, as finger shields or arc deflectors in controllers, heating device insulation, etc., whereas in other cases the insulating material must become liquid or soft, or self-healing under heating or arcing, as in high-tension bushings. A definite amount of wear under abrasion is required in certain construction, as in commutators and magneto distributors, but in other cases, there must be a minimum of abrasive wear, as in rheostat dead segments, wire insulation, etc. Heat conductivity is an important requirement in some instances, as in armature coils, but in other insulation, as in heating devices, a minimum heat conductivity gives greatest efficiency. It is obvious, therefore, that in insulating work diametrically opposite properties are often required in the materials used. It is because of the necessity of meeting these varied requirements that large numbers of insulating materials are now employed in the electrical industry and new materials are constantly being developed.

Porcelain: Porcelain is comparatively inexpensive, chemically inert, and not sensitive to temperature changes. It can be accurately molded or formed to a variety of shapes. There are two main types of porcelain used for electrical insulation: Dry-processed porcelain which is porous and usually suitable only for low-voltage applications, and wet-processed porcelain which is non-porous and used for high-voltage applications.

Lava: Ceramic materials of the so-called lava type, such as steatite, cordierite, rutile, and pyrophyllite, have assumed increasing importance as electrical insulators. Some of these have low power factor at high frequencies, others are highly resistant to thermal shock while still others have a high dielectric constant and low dielectric loss.

Glass: Glass for insulating purposes, like porcelain, is heat and water resistant, unaffected by oils and vapors, and high in crushing strength. Recently developed is a glass fiber material which can be woven into a fabric for wire or coil insulation. When impregnated with varnish, it has excellent insulation resistance at high humidity and also at high temperature. It is receiving increased attention as a motor insulation for severe duty.

Mica: Mica comprises a group of natural silicates distinguished by highly developed basic cleavage into thin, tough, flexible laminae. Mica is especially valuable for commutator insulation because of its evenly laminated structure, resistance to compression, mechanical toughness, resistance to high temperature, and insolubility. White mica is used for undercut commutator insulation, while amber mica, which is softer, is used for flush commutator insulation. Amber mica is also used in heating appliance insulation because of its resistance to higher temperatures. Mica is also used as a sheet insulation with some type of insulating paper or cloth backing.

Marble, Slate and Soapstone: These materials have found general use in slab or plate form for switchboard panels, small switch bases, etc. Soapstone is also machined to form small bushings, beads, and other insulating parts. Their use has, however, greatly declined with the advent of newer materials.

Molded Compounds: Synthetic plastics probably constitute the largest class of new insulating materials, and an almost endless variety of combinations of properties can be obtained uniting appearance and mechanical advantages with the desired electrical characteristics. Some of the types of synthetic plastics used as insulating material are:

Phenolic Formaldehyde: There are a number of kinds of this type of plastic having a wide range of characteristics, such as high heat resistance, good flexural strength, and excellent solvent resistance.

Cellulose Acetate: This material has good color possibilities and good solvent resistance.

Polystyrene: This material has excellent water, acid and caustic resistance, low loss factor, high resistivity and dielectric strength, and high heat insulation value.

Methyl Methacrylate: This material has good acid, caustic and solvent resistance, good heat insulation value, and high dielectric strength.

Ethyl Cellulose: This material has good caustic and solvent resistance, excellent dielectric strength and resistivity, low loss factor, and a high flexural strength which has made it particularly useful as a substitute for enamel on magnet wire.

Urea: This material has high flexural and tensile strength, low loss factor, excellent resistivity, dielectric strength and color possibilities.

Rubber and Rubber Synthetics: Natural rubber has long been used as electrical insulation material. In molded form, it is applied to wire and cable, and, as hard rubber, is also used in a variety of rigid shapes and forms. Synthetic rubber products have recently come to the fore in insulation applications where natural rubber is unsuitable, as, for example, in wire insulation where exposure to oil or ozone produced by corona is anticipated.

Sheet Material: These include various papers, such as so-called fish paper which has a cotton rag base, fullerboard, Kraft paper, rope paper, cellophane, varnish-treated cloth, vulcanized fiber, and laminated phenolic compounds. The papers and cloths are used in plain and impregnated forms for the insulation of coils, while the fiber and laminated phenolic sheets are utilized where a strong, tough and more or less rigid material is needed.

Waxes: Several types of wax are used as impregnating materials for fibrous insulation, such as that used in paper condensers to improve moisture-resisting characteristics.

Oils and Varnishes: One of the most important types of insulating materials used in the construction of motors, generators, and other coil-wound equipment, is varnish. It is particularly valuable as an impregnant and protective coating material to be applied after the forming of coils. It is also widely used in the manufacture of various tapes, sleevings and cloths, such as varnished fabric and fiber glass. A variety of types are available for air-drying or oven-drying. Enamel is also used as an insulating material, and one of its most common applications is for magnet wire insulation.

Oils are used extensively as an insulation for transformers and various types of switchgear where arcing is reduced by its presence. Synthetic oils have been introduced which are superior to mineral oils in some respects, such as inflammability.

Gases: While still in the early stages of development, the use of inert gas as an insulating medium has been found to be practicable—as in power cables, for example. In one instance, 100 pounds of gas of a type similar to that used as a refrigerant was found to provide the dielectric strength of 12,000 pounds of conventional insulating oil.

Intensifier. An intensifier is a hydraulic accumulator consisting of two cylinders of different diameters, the smaller cylinder being contained in the ram or plunger that fits into the larger cylinder. By the use of this machine very high pressures can be obtained.

Interchangeable Manufacture. In 1798, Eli Whitney, inventor of the cotton gin, obtained a contract from the government for 10,000 muskets, built a shop in the outskirts of New Haven, and there laid the foundations of the interchangeable system of manufacture. Using limit-gages, milling machines, and rude jigs, he demonstrated that guns could be manufactured by machine tools, not only interchangeably but more cheaply than by the old hand methods. About the same time, Simeon North, a gun-maker in Middletown, Conn., obtained contracts for pistols, and began a connection with the government which lasted for fifty years. A later contract signed by him in 1813 contained the first clause specifying interchangeability; "the component parts of pistols are to correspond so exactly that any limb or part of one pistol may be fitted to any other pistol of the 20,000." It is probable that the North contract of 1813 was not so much the beginning of the new method as the recognition of one which had already come into existence, as the letters of Whitney himself and the reports of Capt. Wadsworth, the government inspector, show clearly that Whitney, at least, had been developing the idea from 1798. The armory which he founded continued in business for ninety years, when it was sold.

There are several degrees of interchangeability in machinery manufacture. Strictly speaking, interchangeability consists in making the different parts of a mechanism so uniform in size and contour that each part of a certain model will fit any mating part of the same model, regardless of the lot to which it belongs or when it was made. However, as often defined, interchangeability consists in making each part fit any mating part in a certain series; that is, the interchangeability exists only in the same series. Selective assembly is sometimes termed interchangeability, but is merely assembly without fitting. It will be noted that the strict definition of interchangeability does not imply that the parts must always be assembled without hand work, although that is usually considered desirable. It does mean, however, that when the mating parts are finished, by whatever process, they must assemble and function properly, without fitting individual parts one to the other.

When a machine has been installed possibly at some distant point, a broken part can readily be replaced by a new one sent by the manufacturer, but this feature is secondary as compared with the increased efficiency in manufacturing on an interchangeable basis. In order to make parts interchangeable, it is necessary to use gages and measuring tools, to provide some system of inspection, and to adopt suitable tolerances or limits. Whether absolute interchangeability is practicable or not may depend upon the tolerances adopted, the relation between the different parts, and their form. Parts will always interchange if the tolerances are large enough, and the maximum sizes of members such as shafts, etc., do not exceed the minimum sizes of holes which receive them when the machine is assembled; but if the tolerances are too large, the parts may be useless.

Intercoolers for Compressed Air. In compressing air, a great amount of heat is generated due to the friction of the molecules composing the air, which are being crowded into a small space. In compressing air to 100 pounds gage pressure, the final temperature, assuming the compression to be adiabatic, would be about 485 degrees F. The effect of this constant increase in temperature is to tend to expand the air under compression to a larger volume, thus necessitating a corresponding increase of work to compress this apparently increased volume. After the compressed air has been discharged into the receiver or pipe line, the temperature rapidly falls to that of the surrounding atmosphere and the energy due to the heat generated during compression is lost. It, therefore, follows that in compressing air to any great extent, a large amount of work is expended due to temperature conditions, and the only method of reducing to a minimum the amount of work lost is to cool the air during the period

of compression. In theory, the air should be kept at a constant temperature during the period of compression; but the attainment of this is a practical impossibility in air compressors. In modern practice, the work of compression is divided equally between two or more stages. The number of stages depends upon the final air pressure required. An "intercooler" is used between the different stages to reduce the temperature of the compressed air to the normal between the stages. An intercooler built in accordance with modern practice consists of a long shell of cylindrical shape containing a nest of tubes through which cold water is circulated. The air enters at one end of the shell from the low-pressure cylinder at a high temperature, passes around and between the nest of tubes, and enters the high-pressure cylinder at the other end at a greatly reduced temperature.

Interference Bands. See Light Wave Measuring Method.

Interferometer. The interferometer is an instrument of great precision for measuring exceedingly small movements, distances, or displacements, by means of the interference of two beams of light. Instruments of this type are used by physicists and by the makers of astronomical instruments requiring great accuracy. Prior to the introduction of the interferometer, the compound microscope had to be used in connection with very delicate measurements of length. The microscope, however, could not be used for objects smaller than one-half a wave length of light. Two physicists (Professors Michelson and Morley) developed an instrument which was named the *interferometer*, for accomplishing in the laboratory what was beyond the range of the compound microscope. This instrument consisted principally of a system of optical mirrors arranged in such a way as to let the waves of light from a suitable source pass between and through them, the waves in the course of their travel being divided and reflected a certain number of times, thus making it possible to measure objects ten times smaller than was possible with the best compound microscope obtainable. Professor C. W. Chamberlain of Denison University invented another instrument known as the *compound interferometer* which is much more sensitive than the one previously referred to; in fact, it is claimed that it will measure a distance as small as one twenty-millionth of an inch. These compound interferometers have been constructed in several different forms.

An important practical application of the interferometer is in measuring precision gages by a fundamental method of measurement. The use of this optical apparatus is a scientific undertaking, requiring considerable time and involving complex calculations. For this reason all commercial methods of checking accuracy must be comparative, and the taking of fundamental

measurements is necessarily confined to the basic or primary standards, such as are used to a very limited extent for checking working masters, where the greatest possible degree of accuracy is required. The interferometer is used to assist in determining the number of light waves of known wave length (or color) which at a given instant are between two planes coinciding with the opposite faces of a gage-block or whatever part is to be measured. When this number is known, the thickness can be computed because the lengths of the light waves used have been determined with almost absolute precision. The light, therefore, becomes a scale with divisions — approximately two hundred-thousandths inch apart.

Interlocking Safety Device. An interlocking safety device is any means for the protection of workmen against accidents due to the operation of machinery, which is so arranged that it is made mechanically impossible for the operator to set a machine in motion while his hand or fingers, or other parts of his body, are in a dangerous position. In a press for example, it may be necessary to grip two levers, one with each hand, in order to throw the clutch and make the machine operate; in pneumatic devices, two valves may have to be opened, one with each hand; in electric operation, the pressure of two buttons to complete the circuit may be required.

Intermittent Gearing. Intermittent gearing is so designed that the driving gear imparts an intermittent motion to the driven gear, instead of driving it continuously. In many kinds of mechanism, this intermittent motion between a driving and a driven member is required. By using different forms of intermittent gears, the motion may be varied considerably. Some intermittent gearing is so arranged that each revolution of the driver moves the driven gear through part of a revolution, there being several periods of rest for the driven member before it is turned completely around or through one revolution. With other forms of intermittent gearing, the driven gear has only one period of rest for each revolution of the driver; the arrangement may also be such that there are several variable rest periods. Gears of the intermittent type are made in many different designs which are modified to suit the conditions governing their operation, such as the necessity for accurately locking the driven member while idle, speed of rotation, and the inertia of the part connected to the driven gear.

Internal Combustion Engines. Gas and oil engines, generally grouped together under the name *internal combustion engines*, are machines for the transformation of heat into work. They differ from other types of heat engines in that the fuel is

burned within the cylinder or working chamber of the engine, and the products of combustion constitute the working fluid. Internal combustion engines may use a gas, an easily vaporizable liquid, such as gasoline, or a liquid which is difficult to vaporize, such as fuel oil. Engines using gas as fuel are termed *gas engines;* those using gasoline are termed *gasoline engines;* and those using heavy oils are termed *oil engines.* Since the working fluid of all these engines is a highly heated gas, they are all frequently termed "gas engines," instead of using the longer, but more correct, name of "internal combustion engines."

Four-stroke Cycle: During the first stroke of a four-stroke cycle engine, the inlet valve remains open, and the exhaust valve remains closed. The piston is drawn forward by the revolution of the crank, and an intimate mixture of air and fuel or "charge" is drawn into the cylinder; hence, the first stroke of the cycle is called the *suction stroke.* At the end of the suction stroke, the inlet valve closes. As the crank continues to revolve, the piston is pushed back, and since both the inlet and exhaust valves are closed, the charge is compressed into the clearance space. Accordingly, the second stroke of the cycle is called the *compression stroke.* During this stroke, not only does the volume of the charge diminish and its pressure increase, but its temperature also increases, since the temperature of a gas always rises when it is compressed, unless special means are taken during the compression to cool the gas, and so remove the heat which is created in it by the work of compression.

While the engine is on or near the dead-center at the end of the compression stroke, the charge is ignited by an electric spark. The fuel is instantly burned, and a considerable quantity of heat generated. As a result the temperature of the charge is instantly raised, until it reaches a value of between 3000 and 4000 degrees F. This rise in temperature produces a corresponding rise in pressure, which is termed the *explosion.* Immediately after the ignition, the pressure of the charge reaches a value of from 250 to 700 pounds per square inch. After the explosion, the crank continuing to revolve, the piston again moves forward, both valves remaining closed. This is the power producing stroke. The charge expands in volume, forcing the piston forward. In consequence, this stroke of the cycle is called the *expansion stroke.* The work done by the expanding charge upon the piston is largely expended in accelerating the flywheel, which acts as a reservoir of energy. At the end of the expansion stroke, the exhaust valve opens, and the pressure of the charge falls to that of the atmosphere. The revolving crank forces the piston back, and the burned charge is expelled from the cylinder, during the fourth stroke, termed the *exhaust stroke,* and the cycle is complete. It will be noted

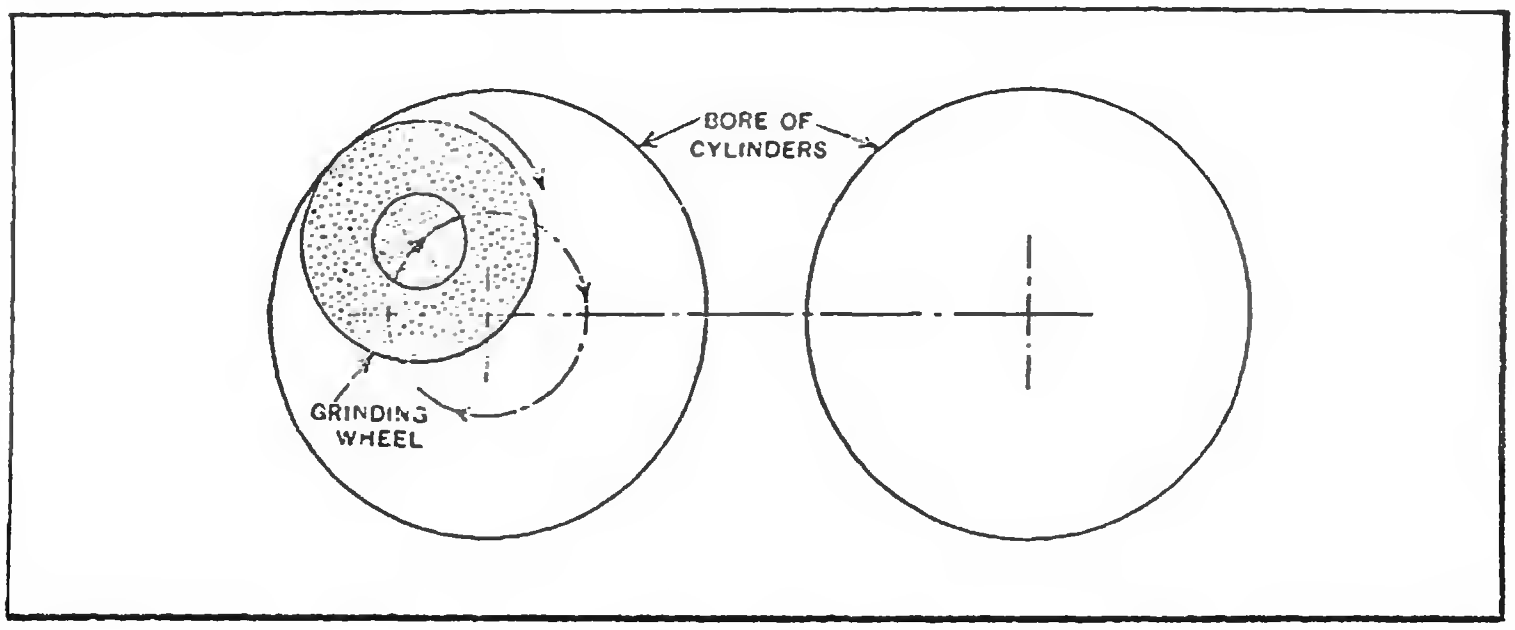
that the cycle requires four strokes or two full revolutions of the crankshaft.

Two-stroke Cycle: In a two-stroke cycle engine the piston acts as both an inlet and exhaust valve. Assume that the cylinder is filled with a mixture of air and fuel. The crank revolves, the piston rises, and the charge is compressed. When the piston is at or near its highest point, the charge is ignited, and the piston descends. During its upward stroke, the piston draws into the crankcase (which is an air-tight casting containing the crank and connecting-rod) a fresh quantity of charge, through the check-valve. During its downward stroke, the piston compresses this charge. When the piston approaches the bottom of its stroke, its motion uncovers an exhaust port, so that the burned charge escapes, and the pressure falls. An instant later the motion uncovers an inlet port, and the fresh charge forces its way in from the crankcase, driving the remainder of the burned charge before it. A projection on the top of the piston is for the purpose of deflecting the fresh charge, and preventing it from passing directly across the cylinder, and out at the exhaust. Engines of this type, using gasoline for fuel, are frequently employed for marine and stationary service whereas the four-stroke cycle engines are used on motor cars, airplanes, and for various other purposes.

Internal Expanding Clutch. This is a friction clutch provided with shoes which are forced outward against an enclosing drum by the action of levers connecting with a collar free to slide along the shaft. The engaging shoes are usually lined with wood.

Internal Gears. An internal spur gear has teeth formed on an interior surface instead of on an exterior one as in the case of an ordinary spur gear. Briefly, and perhaps somewhat unconventionally defined, it is an ordinary spur gear turned inside out. There are some advantages incident to the use of internal gears for particular applications, as compared with external gears of the same pitch and number of teeth. An internal gear has its teeth and those of its pinion protected to a very marked degree from inflicting or receiving injury, often making the use of a gear guard unnecessary, if the parts are properly designed in this respect. Owing to the fact that the cylindrical pitch surfaces in internal gearing have their curvature in the same direction, the teeth of the pinion approach and mesh with those of its mate somewhat more gradually and easily than when they are meshing with an external gear. This tends toward smoothness and quietness in running, as well as giving a slightly longer contact for each tooth. Internal gears of the same pitch and number of teeth have a much smaller center distance than external gears, which is often an advantage.

Cutting Methods: Internal spur gears are usually cut by one of the following methods: (1) By using a formed cutter and milling the teeth; (2) by a molding-generating process, as when using a Fellows gear shaper; (3) by planing, using a machine of the templet or form-copying type (especially applicable to gears of large pitch); and (4) by using a formed tool which reproduces its shape and is given a planing action either on a slotting or a planing type of machine. The machines used ordinarily for cutting internal gears are designs intended primarily for external gears. These machines may be arranged for internal gear-cutting by using some form of attachment which provides means of holding the cutter in the position required for forming gear teeth around an inner surface.



Action of Planetary or Eccentric-head Type of Cylinder Grinder

Internal Bevel Gear: The pinion cone of an internal bevel gear rolls on the interior surface of a concave gear cone, while in the more common type of bevel gearing, the pinion cone rolls upon the exterior surface of a convex gear cone; hence, the pitch cone angle of an internal gear is greater than 90 degrees.

Internal Gears, Williams. In the Williams system, the profiles of the internal gear teeth are straight lines, so that the tooth spaces are similar to those of an involute rack, while the teeth of the mating pinion have curved profiles of conjugate form. This gearing is designed to secure a much longer arc of tooth contact, improved operating action, reduced wear, and increased strength of the pinion teeth.

Internal Grinding Machines. On one type of internal grinding machine the work head is stationary and the wheel-spindle is traversed. The wheel-spindle of another type is supported by a stationary portion of the frame, and the work head is mounted on the table of the machine and travels to and from the grinding

wheel. The former type is used to a large extent in machines especially designed for internal grinding. Some machines, instead of being designed for internal grinding exclusively, are combination types which will grind both internal and external diameters on the work at the same chucking. In the design of internal grinders much attention has been given to the spindle and its mounting in order to obtain the high-speeds essential to efficient grinding.

For grinding cylinders, a special type of internal grinding machine has been developed in which the work does not have to be rotated, as is the case with the ordinary type of internal grinding machines. The grinding wheel not only rotates about its own axis but has a circular or planetary movement (as indicated by the diagram) so that it follows around the walls of the hole being ground as the work is fed in a lengthwise direction.

Internally-Fired Furnaces. The heating chamber and the combustion chamber of some furnaces are combined. This arrangement is applicable to forge furnaces, rod and rivet heaters, etc., in which an intense heat is required, and the work will not be seriously affected by the direct action of the flame. Melting furnaces of some types are also internally fired. It is but rarely desirable to have the flame proper strike directly against the cold work, as combustion is thereby retarded and soot is often deposited on the work, particularly when oil fuel is used. This type is largely confined to the use of gas and oil fuel. The common pit type of crucible melting furnace, using coke or hard coal, is a notable exception.

Internal Stresses. Castings are sometimes sprung out of shape by the internal stresses existing in the casting itself. These stresses are caused by the unequal cooling of the casting in the foundry. When a casting is made, the molten metal which comes in contact with the walls of the mold naturally cools first and, in cooling, contracts and becomes solid while the interior is still more or less molten. The result is that when the interior cools and contracts, the tendency is to distort the part which solidified first, and internal stresses are left in the casting.

International Atomic Weights. These are atomic weights which are based upon the value of the atomic weight of oxygen as 16.

International Electrical Units. A great deal of confusion occurred in the early days of electrical development because of the many changes in electrical standards. These standards were an attempt to define certain basic electrical units in terms of mechanical quantities. One of the early difficulties was the lack of accurate means of measurement; and as this accuracy was im-

proved, changes to correct errors in previous standards were made necessary. A series of International Congresses, meeting during the period from 1881 to 1908, worked toward the establishment of international electrical standards, and finally agreement was reached by a specially appointed International Commission which met in London in 1908. Based on this agreement, the ohm was defined from physical measurements as the first primary standard, the ampere was defined from physical measurements as the second primary standard, and the volt was established as a derived unit based on the ohm and the ampere.

The international ohm was defined as the resistance at zero degrees Centigrade of a column of mercury of uniform cross-section having a length of 106.300 centimeters and a mass of 14.4521 grams.

The international ampere was defined as the current which will deposit silver at the rate of 0.00111800 gram per second.

The international volt is a voltage that will produce a current of one international ampere through a resistance of one international ohm.

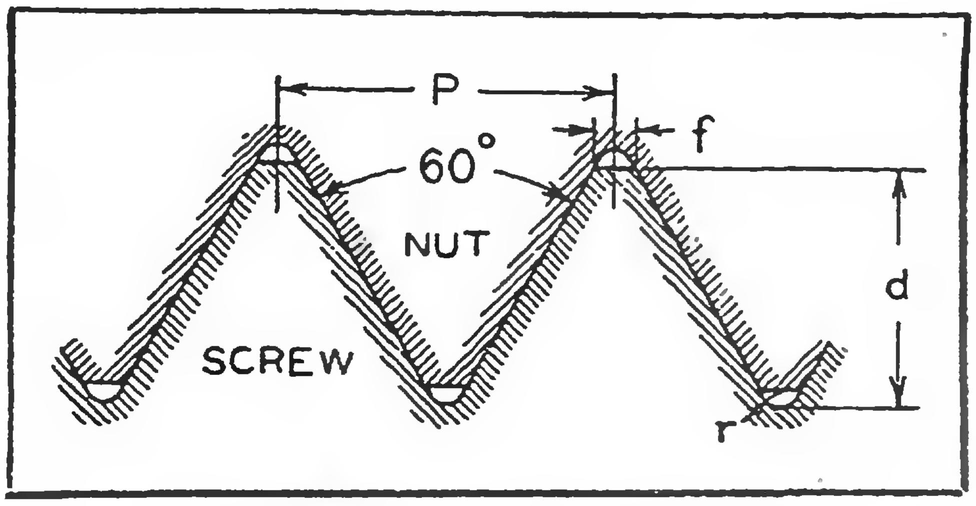
Some international units differ very slightly from the so-called "theoretical" practical units which are based upon the assumption of a fictitious magnetic quantity similar to the electric quantity or charge. Thus, experimental results show that the international ohm equals 1.0005 "theoretical" ohms.

These international units have, however, been discarded; and for standard measurements, the definitions of the theoretical (absolute) units, as internationally accepted, are now recommended for use. These theoretical units are not, in themselves, based upon primary standards kept in certain laboratories, but are derived from significant experimental laws.

International Metric Thread System. The Systeme Internationale Thread was adopted at the Internationale Congress for the standardization of screw threads held in Zurich in 1898. The thread form is similar to the American standard (formerly U. S. Standard), excepting the depth which is greater. There is a clearance between the root and mating crest fixed at a maximum of 1/16 the height of the fundamental triangle or 0.054 $\times$ pitch. A rounded root profile is recommended. The angle in the plane of the axis is 60 degrees and the crest has a flat like the American standard equal to 0.125 $\times$ pitch. This system has been adopted as standard by the International Standards Association, by most European countries using the metric system and by Japan. The original specification has been modified by the general adoption of a uniform pitch of 6 millimeters for the 72-, 76- and 80-millimeter sizes. The range of nominal diameters has also been extended beyond the original 80-millimeter maximum to 84

and then by increases of 5 millimeters with a constant pitch of 6 millimeters. Thread depth $d = 0.7035\ P$ max. and $0.6855\ P$ min. Radius r at root $= 0.0633\ P$ max. and $0.054\ P$ min.

The German metric thread form is like the International Standard but the thread depth $= 0.6945\ P$. The root radius is the same as the maximum for the International Standard or $0.0633\ P$.



International Metric Thread

International Metric Fine Thread: The form of thread is the same as the International system but the pitch for a given diameter is smaller. The metric fine thread is used on the European continent, although there is not as yet complete uniformity.

Interpolation. In mathematics, interpolation is the process of finding a value in a table or in a mathematical expression which falls between two given tabulated or known values. In engineering handbooks, the values of trigonometric functions are usually given to degrees and minutes; hence, if the given angle is to degrees, minutes and seconds, the value of the function is determined from the nearest given values, by interpolation.

Interpolation to Find Functions of an Angle: Assume that the sine of 14° 22′ 26″ is to be determined. It is evident that this value lies between the sine of 14° 22′ and the sine of 14° 23′. Sine 14° 23′ = 0.24841 and sine 14° 22′ = 0.24813. The difference = 0.24841 — 0.24813 = 0.00028. Consider this difference as a whole number (28) and multiply it by a fraction having as its numerator the number of seconds (26) in the given angle, and as its denominator 60 (number of seconds in one minute). Thus $26/60 \times 28 = 12$ nearly; hence, by adding 0.00012 to sine of 14° 22′ we find that sine 14° 22′ 26″ = 0.24813 + 0.00012 = 0.24825. The correction value (represented in this example by 0.00012) is *added* to the function of the *smaller* angle nearest the given angle in dealing with *sines* or *tangents* but this correction value is *subtracted* in dealing with cosines or cotangents.

Interpolation to Find Angle: Example: Find the angle whose cosine is 0.27052. A table of trigonometric functions shows that the desired angle is between 74° 18′ and 74° 19′ because the cosines of these angles are, respectively, 0.27060 and 0.27032. The difference = 0.27060 — 0.27032 = 0.00028. From the cosine of the *smaller* angle or 0.27060, subtract the given cosine; thus 0.27060 — 0.27052 = 0.00008; hence, $8/28 \times 60 = 17''$ or the

number of seconds to add to the smaller angle to obtain the required angle. Thus the angle whose cosine is 0.27052 = 74° 18′ 17″. Angles corresponding to given sines, tangents, or cotangents may be determined by the same method.

Invar. Invar is a nickel steel containing about 36 per cent nickel, together with about 0.5 per cent each of carbon and manganese, with metallurgically negligible quantities of sulphur, phosphorus, and other elements, the remainder being iron. It is made either in the open-hearth furnace or by the crucible method. It melts at about 1425 degrees C. (about 2600 degrees F.). The value of this alloy lies in the fact that it has a very small coefficient of expansion due to heat, and it is, therefore, used in scientific instruments, for standard length measurements, and in high-grade measuring tapes.

Invention, What Constitutes. See Patents.

Inventors, Joint. See Joint Inventors.

Inverted Synchronous Converter. This is a rotating electrical machine used for converting direct current into alternating current; see Synchronous Converter.

Inverted Type Accumulator. A hydraulic accumulator in which the cylinder, fitting over the plunger from above, supports the weights necessary to produce the required pressure, is known as an inverted type accumulator.

Investment Casting. Commonly known as the "lost wax" process although more properly called "precision investment casting." This technique has been known and used for centuries by jewelers and makers of bronze sculptures. In this process a mold or die is made, usually of metal, and is filled with hot wax. When the wax has set, the mold is opened and a wax pattern is obtained. Several of these patterns are attached to a central wax stalk to form a "tree." This is then placed in a container which is filled with a special type of plaster called "the investment." After the plaster has set, the container is placed in a furnace and baked to thoroughly dry and harden the investment. The heat burns out the wax (hence the term "lost wax") leaving a cavity into which molten metal is poured.

Castings made by this process are accurate to within about three one-thousandths of an inch, but because the method is relatively slow and expensive it is employed chiefly for small precision parts and for costly high-melting-point metals which are so hard that they cannot be machined by conventional methods but must be cast to size as nearly as possible.

Involute. If a circular disk were placed upon a drawing-board, an involute curve would be described by the end of a taut line if the latter were unwound from this disk, in the plane of the board. The disk represents, in gear design, what is known as the *base circle*, because it is from this circle that the involute tooth curves are derived.

Involute Function. Involute functions are used in involute trigonometry or in certain formulas for solving problems relating to involute curves, as in the case of involute gearing. For example, involute functions are used in the basic formulas for checking the sizes of involute gears, either by measurement over pins or by the chordal measurement over two or more teeth. Involute function = tangent of angle — angle in radians.

For example, find the involute function of 19.09 degrees:

Tangent = 0.34608560. 19.09 degrees is equivalent to 0.33318335 radians.

0.34608560 — 0.33318335 = 0.01290225 which is the involute function.

Involute Gear Teeth. The involute curve is made use of in forming the teeth of the involute system of gearing, which is the system used for practically all cut-gear teeth. The involute gear-tooth system has the advantage over the cycloidal tooth system in that gears with involute teeth will run correctly even if the distance between the centers of the gears is not theoretically correct. The relative velocities of two gears having involute teeth will be the same even if their center distance is altered. The unmodified involute rack tooth has straight sides, but in practice the points may be slightly rounded off to avoid interference. The basic rack of the American Standard 14½ Degree Composite System has cycloidal curves above and below a straight mid-section. See Gear Tooth Standardization.

Involute Measuring Machine. The design of the Fellows involute measuring machine for checking gear tooth profiles is based on the fact that all involutes developed from the same base circle are alike. A single master cam is used for checking the teeth of any size gear within the capacity of the machine. The master cam takes the place of the "base roll" employed in previous machines, which required a different size roll for each size or diameter of gear tested.

The master involute cam is developed from a base circle having a radius greater than that of the largest size gear accommodated by the machine. Thus, any gear having a smaller base-circle radius than the master cam can be checked by simply changing the position or radial distance of the pointer from the axis of the

gear. The rate of travel of the slide that carries the indicator is changed automatically to agree with the base-circle setting.

The pointer that checks the involute is automatically set to the required base-circle radius by locating the main slide in the correct position by means of standard size-blocks. A size-block is also employed for setting the pointer in the correct "radial" or "starting" position.

In cases where it is necessary to measure a modified form of involute, a graduated dial is employed which moves with the work, and, in conjunction with the dial indicator, measures the exact amount that the involute is modified and the angle through which the profile is modified. This device can also be employed for determining the height of the fillet and for checking the flanks of gear-shaper cutters. The machine can also be used to determine the base-circle diameter of a gear.

Involute Splines and Serrations. See Splines and Serrations.

Involute Splines, Rolled. See Gears, Rolled.

Iodine Number. Iodine value or number is the number of milligrams of iodine that one gram of a fat or oil will absorb under specific conditions, and for fixed oils the iodine value is usually fairly constant, marked variation indicating adulteration.

Ion. An ion is an electrified portion of matter of sub-atomic, atomic, or molecular dimensions. An *anion* is an ion that is negatively charged. A *cation* is an ion that is positively charged.

Ionization. When certain substances, such as salts of various kinds, are dissolved in water, they tend to break up or dissociate into an equal number of negatively charged and positively charged elements or particles. These elements or particles are called *ions* and are supposed to be atoms or groups of atoms which have gained or lost a certain number of electrons, thus giving them a positive or negative charge. The solution is said to be ionized; and when it is used to conduct an electric current, it is called an *electrolyte*.

Iridio-Platinum. Iridio-platinum is an alloy of iridium and platinum, containing about 10 per cent of iridium and 90 per cent of platinum. The alloy is used for international weight standards, electrodes exposed to acid liquids, and wires forming part of high-temperature pyrometers. It is a remarkably hard alloy, susceptible of high polish. Very few chemical reagents attack it.

Iridium. Iridium is one of the metallic chemical elements of the platinum group, its symbol being Ir, and its atomic weight,

193.1. It is a metal of silvery-white color and is always present in platinum ores in the form of alloys of platinum and iridium and of osmium and iridium. It is a brittle, hard metal and is one of the heaviest substances known, its specific gravity being 22.42, which is equivalent to a weight per cubic inch of 0.809 pound. Iridium is fusible only with great difficulty, its melting point being at 2300 degrees C. (about 4170 degrees F.). Practically all commercial platinum contains iridium. It is used for the points of gold pens in fountain-pen manufacture, and is also alloyed with platinum to act as a hardener for this metal. Very little pure platinum is now being used, nearly all the commercial metal passing under this name being so-called "hard platinum," which is an alloy of platinum and iridium.

Iridosmium. Iridosmium is an alloy of the metals iridium and osmium, which is found in nature in different proportions. The alloy has a specific gravity varying from 19.3 to 21, and a hardness almost equal to that of quartz. The color resembles that of tin or steel. The alloy usually contains small percentages of rhodium, ruthenium, and platinum. It is found in connection with platinum ores in the Ural Mountains and in Northern California.

Iron. The term "iron," as used in the chemical or scientific sense of the word, refers to the chemical element iron or pure iron, which is the chief constituent in all commercial iron and steel. As applied to the commercial product, however, the term "iron" is most generally used to indicate wrought iron, as distinguished from steel or cast iron. Pure iron is not used in the industries, but all the commercial products containing iron as the chief element—wrought iron, cast iron, steel castings, Bessemer steel, open-hearth steel, crucible steel, alloy steel, etc.,—contain also small percentages of carbon and a number of other elements, the presence of which determine the characteristics of each class of commercial iron and steel. Iron is found in nature in the form of iron ore, and all the irons and steels used in the industries are produced from iron ore by a number of different processes.

Pure iron is silvery white, tenacious, malleable, ductile, and has a high melting point. The chemical symbol of iron is Fe, its atomic weight is 55.84, and its specific gravity, 7.84, giving a weight per cubic inch of 0.283 pound. Its linear expansion per unit length in degrees F. is 0.0000065, and its average specific heat for temperatures between 60 and 212 degrees F., 0.11; this value of the specific heat increases with the temperature, up to about 1550 degrees F., and then diminishes. The melting point of pure iron is given by the Bureau of Standards as 1520 degrees C. (2768 degrees F.).

Iron, Acid-Resisting. See Duriron.

Iron and Steel Definitions. The International Association for Testing Materials adopted the following definitions of the most important forms of iron and steel:

Alloy Cast Irons: Irons which owe their properties chiefly to the presence of an element other than carbon.

Alloy Steels: Steels which owe their properties chiefly to the presence of an element other than carbon.

Basic Pig Iron: Pig iron containing so little silicon and sulphur that it is suited for easy conversion into steel by the basic open-hearth process (restricted to pig iron containing not more than 1.00 per cent of silicon).

Bessemer Pig Iron: Iron which contains so little phosphorus and sulphur that it can be used for conversion into steel by the original or acid Bessemer process (restricted to pig iron containing not more than 0.10 per cent of phosphorus).

Bessemer Steel: Steel made by the Bessemer process, irrespective of carbon content.

Cast Iron: Iron containing so much carbon or its equivalent that it is not malleable at any temperature. The committee recommends drawing the line between cast iron and steel at 2.20 per cent carbon.

Cast Steel: The same as crucible steel; obsolete, and confusing: the terms "crucible steel" or "tool steel" are to be preferred.

Crucible Steel: Steel made by the crucible process, irrespective of its carbon content.

Gray Pig Iron and Gray Cast Iron: Pig iron and cast iron in the fracture of which the iron itself is nearly or quite concealed by graphite, so that the fracture has the gray color of graphite.

Malleable Castings: Castings made from iron which when first made is in the condition of cast iron, and is made malleable by subsequent treatment without fusion.

Malleable Iron: The same as wrought iron.

Malleable Pig Iron: An American trade name for the pig iron suitable for converting into malleable castings through the process of melting, treating when molten, casting in a brittle state, and then making malleable without remelting.

Open-hearth Steel: Steel made by open-hearth process irrespective of its carbon content.

Pig Iron: Cast iron which has been cast into pigs direct from the blast furnace.

Puddled Iron: Wrought iron made by the puddling process.

Refined Cast Iron: Cast iron which has had most of its silicon removed in the refinery furnace, but still contains so much carbon as to be distinctly cast iron.

Steel: Iron which is malleable at least in some one range of temperature and, in addition, is either (*a*) cast into an initially

malleable mass; or, (*b*) is capable of hardening greatly by sudden cooling; or, (*c*) is both so cast and so capable of hardening.

Steel Castings: Unforged and unrolled castings made of Bessemer, open-hearth, crucible, or any other steel.

Washed Metal: Cast iron from which most of the silicon and phosphor have been removed by the Bell-Krupp process without removing much of the carbon, still contains enough carbon to be cast iron.

Weld Iron: The same as wrought iron; obsolete and needless.

White Pig Iron and White Cast Iron: Pig iron and cast iron in the fracture of which little or no graphite is visible, so that their fracture is silvery and white.

Wrought Iron: Slag-bearing, malleable iron, which does not harden materially when suddenly cooled.

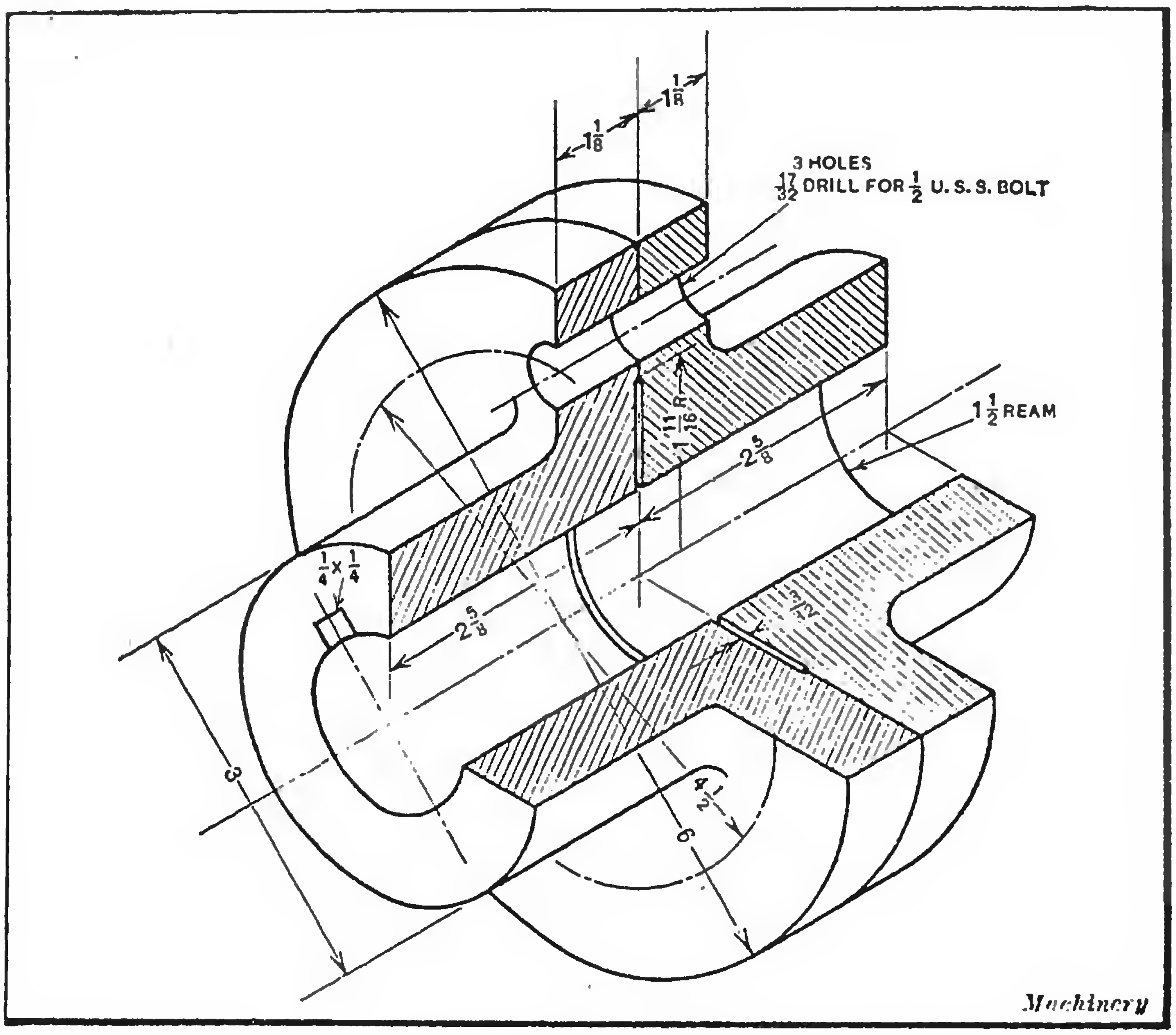
Iron in Iron Ore. Iron ore contains ordinarily from 35 to 65 per cent of iron, and, in addition, oxygen, phosphorus, sulphur, silica (sand), and other impurities. If the ore contains less than 40 per cent of iron, it must first be concentrated, and, if less than 25 per cent of iron, it is not considered a commercial product, owing to the excessive cost of smelting. The ores mined in the United States average slightly over 50 per cent of iron, although the "Lake" ores sometimes contain over 60 per cent. Iron ores which consist of carbonates—minerals in which iron is present with oxygen and carbon—and sulphides—minerals in which the iron is present with sulphur—are also used, but these ores must be roasted to drive off the carbonic acid of the carbonate ore and reduce the sulphur in the sulphide ore. Iron ore in which sulphur is present to an amount exceeding 1 per cent must always be treated in this manner. Magnetite is an ore that has derived its name from the fact that it is attracted by the magnet. In magnetite ores, iron is present as a magnetic oxide, Fe_3O_4, which, when pure, contains 72.4 per cent of iron. See also Magnetite, and Hematite.

Iron Ore Grading. Iron ore is graded according to the percentage of phosphorus it contains. A low percentage of phosphorus—under 4½ per cent—makes it available for the Bessemer steel-making process, and such ore is called Bessemer ore. The non-Bessemer ore, which contains a higher percentage of phosphorus, is made into steel by the basic open-hearth process, which admits of the elimination of the phosphorus.

Isolantite. Isolantite is the name of a material that is claimed to be harder than glass, but not brittle, having a toughness greater than cast iron, that it is capable of resisting in-

candescent heat followed by a plunge in cold water without damage, that it is practically moisture-proof, and that it can be produced in a soft state so that it can be machined into all kinds of shapes and sizes with great precision, and can have threads cut on it, after which it can be hardened to obtain the extreme properties mentioned. It is unaffected by commercial acids, alkalis, and solvents, and makes an effective electrical insulator. When in its soft state, it is turned, drilled, milled or threaded in the same manner as metal. The threads are said to be even stronger than metal threads, and machine screws screwed into threaded "Isolantite" are said to have been stripped of their threads before the threads in the "Isolantite" gave way. The material is pure white and smooth in its finished state.

Isometric Projection. In ordinary mechanical drawing, the orthographic method of projection is used, the object being represented in two or more views in which all lines are drawn to the same scale. Another system of representing objects, known as "isometric projection" is used to show in one view the appear-



Isometric Drawing of a Shaft Coupling

ance and the dimensions of an object in all directions; that is, to show both length or height, breadth or width, and thickness. The isometric method of projection differs from perspective drawing in that it shows the object in its true dimensions, all lines in any given direction being drawn to some given scale, and all lines that are parallel in the object being shown parallel in the drawing. The perspective drawing, on the other hand, shows the object as it would appear to the eye, the lines converging toward a common vanishing point. The illustration shows an isometric drawing of a shaft coupling, partly in section. Note that the

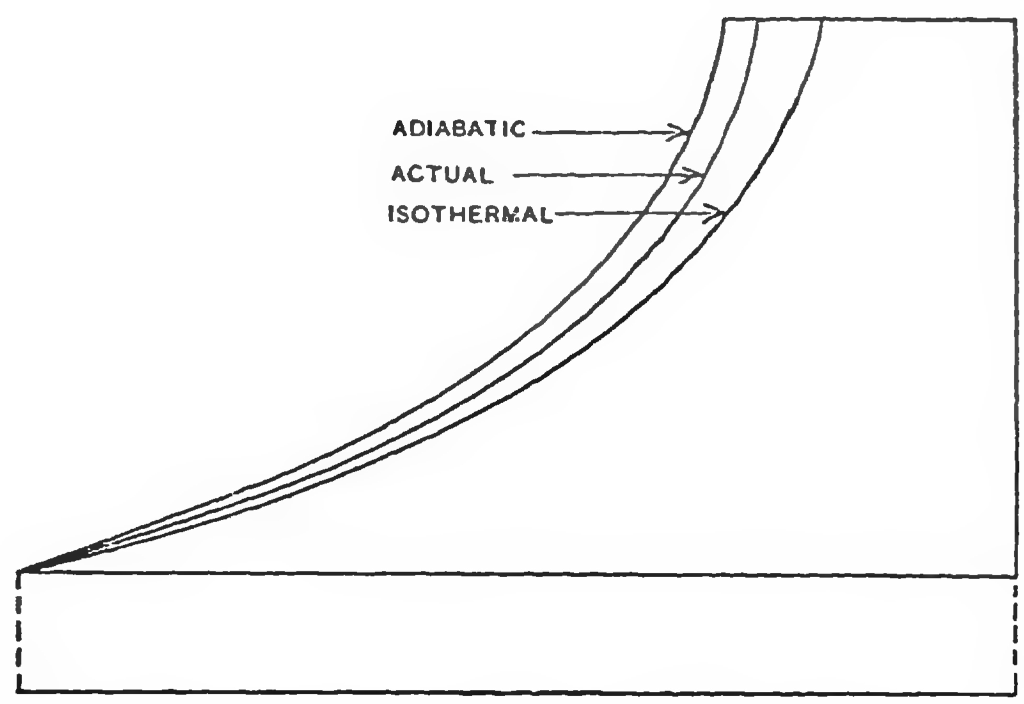


Fig. 1. Adiabatic, Actual, and Isothermal Curves of Compression

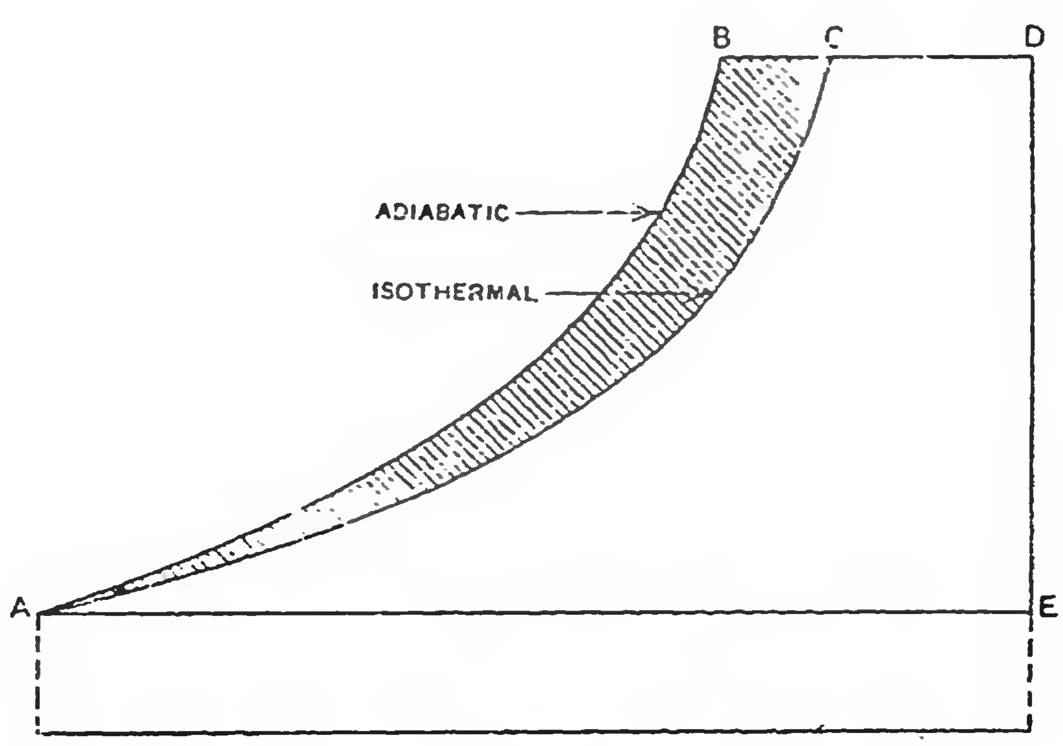


Fig. 2. Additional Work Required for Adiabatic over Isothermal Compression

hub thickness, for example, is the same at each end of the drawing.

Isothermal Expansion and Compression. When a given volume of gas expands, the temperature naturally decreases, assuming that heat is not supplied to compensate for the loss due to expansion. If the expanding gas has enough heat added to it to keep the temperature constant, the expansion is isothermal and a curve representing such expansion is sometimes called the expansion curve of constant temperature.

When air is compressed, heat is generated and the temperature rises. If this heat could be removed as fast as generated, so as to maintain a constant temperature during the process of compression, *isothermal* compression would be obtained. If it were possible to compress air without adding to or removing the heat generated by the process of compression, *adiabatic* compression would be obtained. In the actual compression of air under practical working conditions, neither of these results is obtained, the curve of compression lying between the two, somewhat as shown by the diagram. The isothermal curve is only approached in the case of slow-speed machines where the air is in contact with the water jackets for a longer period than usual. In the ordinary type of compressor, working under normal conditions, the curve lies nearer to the adiabatic, as indicated by the upper illustration, Fig. 1, and for this reason practical computations in connection with the design of compressors are usually based on adiabatic compression. The power requirements, however, are greater for adiabatic than for isothermal compression, due to the higher temperature of the air and the increased volume for a given pressure. This is shown graphically by the lower diagram, Fig. 2, the area *ABDE* representing the work required to compress and discharge a given volume of air adiabatically, and *ACDE*, the work required to compress and discharge the same volume of air to the same pressure isothermally. The shaded portion *ABC* represents the saving in power which might be made, were it possible to secure isothermal compression under practical working conditions. The energy represented by this area is wasted, so far as useful work is concerned, because, being in the form of heat, it is all lost by radiation before the air is used. Furthermore, the excessive temperature of the air at high pressures vaporizes the lubricating oil in the cylinder, thus forming an explosive mixture which may become ignited and cause serious damage.

Isotope. An isotope is an atom of a chemical element that has a different weight than that normally attributed to atoms of that element. This is due to the fact that there are a differ-

ent number of neutrons in the nucleus of this atom, although the number of protons in the nucleus and the number of electrons outside the nucleus are the same as would normally be expected. An element may have atomic forms such that there are as many as nine isotopes occurring naturally. Some elements come in only one atomic configuration so that there are no known isotopes.

Izod Impact Test. See Impact Tests.

J

Jacks. Lifting jacks are made in many different types and sizes, ranging from the small jacks used for leveling and supporting work on planers to the powerful hydraulic jacks capable of lifting a locomotive or even greater weights. The mechanism by means of which jacks are operated also varies greatly. One of the simplest types consists of a screw which is inserted in a suitable base. There are also the gear-and-rack and the lever-and-rack types, in addition to many different designs that are hydraulically operated. While the lifting capacity varies greatly, in general, screw-jacks and those belonging to the reduction gear-and-rack class are capable of lifting loads up to about twenty tons, whereas those operated by hydraulic power ordinarily vary in capacity from four or five tons up to about five hundred tons.

Jacks, Hydraulic. See Hydraulic Jacks.

Jacoby Metal. Jacoby metal is a tin-antimony-copper alloy having a composition similar to britannia metal. It is suitable to be used for plated ware. The composition is as follows: Tin, 85 per cent; antimony, 10 per cent; and copper, 5 per cent. It can also be used as a high-grade bearing metal.

Jal-Ten. Open-hearth manganese copper-bearing steel with high resistance to weather corrosion. Minimum tensile strength, 80,000 pounds per square inch; minimum yield point, 50,000 pounds per square inch; minimum elongation in 2 inches, 20 per cent; minimum Brinell hardness, 160. Three times greater resistance to atmospheric corrosion than ordinary open-hearth steel. Specifically suitable for railway car construction and for all purposes where high strength, resistance to abrasion, and resistance to all types of corrosion such as would be met with in railway service are required.

Jamb Coke. Jamb coke also known as "soft coke" and "heating coke," is the coke that is obtained next to the back and front of the coke oven and around the oven doors when producing regular foundry and furnace coke.

Jam-Nut. A jam-nut is a secondary nut which is used in conjunction with the regular holding nut on a bolt, the object of the jam-nut being to keep the other nut from working loose, due to vibrations. Jam-nuts are also known as *check-nuts* or *lock-nuts.* It is preferable to put the jam-nut below the regular nut instead of above it, as is often done by mechanics. The jam-nut

ordinarily is made about five-eighths the thickness of the regular nut. The regular nut thickness is about seven-eighths of the diameter of the bolt. The reason why the thinner jam-nuts should be placed below and the thicker regular nuts on top is that the pressure on the threads of the lower nut is small compared with the pressure on the threads of the upper nut, if the nuts are tightened in such a manner that they actually bind each other in place. The upper nut must be tightened down so as to place a greater stress on the bolt than is placed on it by the lower nut, because in order to secure a locking action the nuts must bear against opposite sides in the thread. If the upper nut is not tightened down so as to place such a stress on the bolt that the nuts bear on opposite sides of the thread, then the check-nut does not act as a check-nut at all, but merely increases the length of the nut already in place. This may have some tendency to prevent the nut from jarring loose, but it is not the condition actually sought.

Japanese Alloys. Metal alloys used for Japanese art work are composed mainly of copper with a number of other metals. One analysis shows 94-5 per cent of copper; 3.7 per cent of gold; 1.5 per cent of silver; 0.1 per cent of lead; with small percentages of zinc and iron. Another alloy is composed of 67.3 per cent copper; 32 per cent of silver; and 0.5 per cent of lead; with small percentages of gold, zinc, and iron. Another easily fusible metal for casting in plaster-of-paris is composed of 91.4 per cent of copper; 5.7 per cent of tin; and 2.9 per cent of lead. The term "Japanese alloy," therefore, does not signify any one composition.

Japanning. Japanning is a process that consists of applying an opaque, usually black, varnish to the surface of the object to be japanned, and baking it on the surface by means of high temperature in a japanning oven. The art of japanning originated with the Japanese; hence, the name. The Japanese made their varnish or liquor from the secretions of certain kinds of trees. These, upon being exposed to the air, assumed a deep, dark color, to which pulverized charcoal was then added. The varnish so made was applied to the surface of the object to be coated in several successive coats. Each coat of varnish was baked on the surface in the sun before the next coat was applied. After the final coat had been baked on, it was polished, thus producing a smooth, glossy surface. The modern methods of japanning are different in everything, except the principle, from the methods used by the Japanese. The japan varnish used at the present time in manufacturing processes is composed generally of asphaltum, gum, linseed oil, turpentine, benzine, and some coloring matter, such as charcoal or boneblack. Objects may be coated with japan to protect them or for decorative purposes.

Jarno Taper. The Jarno taper was originally proposed by Oscar J. Beale of the Brown & Sharpe Mfg. Co., Providence, R. I. No table is necessary for the Jarno taper socket, as this socket is based on such simple formulas that practically no calculations are required when the number of taper is known. The taper per foot of all Jarno taper sizes is 0.600 inch on the diameter. The diameter at the large end is as many eighths, the diameter at the small end is as many tenths, and the length as many half inches as are indicated by the number of the taper. For example, a No. 7 Jarno taper is 7/8 inch in diameter at the large end; 7/10, or 0.700 inch at the small end; and 7/2, or 3½ inches long. The Jarno taper is used on various machine tools, especially profiling machines and die-sinking machines.

Jet Condenser. The jet condenser condenses the exhaust steam of a steam engine or turbine by mixing the condensing or cooling water directly with the steam. In one type the exhaust steam enters at the top of the condenser, meeting the injection or cooling water, which is drawn in by suction due to the partial vacuum, and is discharged in the form of a spray, resulting in complete condensation of the steam. A greater drop in pressure for a given amount of cooling water is obtained in a jet condenser than in a surface condenser.

Jewelers' Borax. Jewelers' borax, also known as octahedral borax, is a form of borax suitable for use as a flux in soldering or welding.

Jib Crane. A jib crane consists of a post or pillar supported and pivoted at top and bottom, from which a horizontal arm or jib extends. The jib has a crab or trolley moving in a radial direction along it. Generally, the jib is supported by a strut placed in an inclined direction between the vertical post and the jib.

Jig-Boring Machine. The jig-boring machine is designed expressly for jig boring or similar work and is so arranged that either the part to be bored, or the boring spindle or spindles (or both work and spindles) can be adjusted to accurately locate the holes at given center-to-center distances without preliminary measurements or laying out. One design of jig-boring machine has a single spindle adjustable on a cross-rail located above a horizontal work-table, which may be adjusted along its bed in a direction at right angles to the cross-rail. With this machine, the work is located in the required position by moving the horizontal work-table lengthwise and the vertical spindle laterally along its cross-rail. Another type of jig-boring machine which is extensively used is so designed that adjustments for locating

various holes to be bored are obtained by lengthwise and lateral or cross-adjustments of a compound type of work-holding table.

Measuring Devices: Jig-boring machines are equipped with accurate means of measuring the longitudinal and lateral adjustments for boring various holes to given dimensions within close limits. Some machines have precision lead-screws with micrometer dials. Another type of measuring device consists of vernier scales which show the lengthwise and lateral measurements. A third method consists in using end-measuring rods and micrometers between adjustable stops. To obtain greater refinement and insure uniform measuring pressure for all measurements, contact at one end may be with a dial gage. Linear scales may be used in conjunction with the end-measuring micrometers, for approximate adjustments.

Jig Bushings, Standard. The American standard covers the different types of jig bushings in common use. This standard includes a range of bushing sizes and also the following types of bushings:

Renewable Bushings: Renewable wearing bushings to guide the tool are for use in liners which in turn are installed in the jig. They are used where the bushing will wear out or become obsolete before the jig or where several bushings are to be interchangeable in one hole.

Press Fit Bushings: Press fit wearing bushings to guide the tool are for installation directly in the jig without the use of a liner and are employed principally where the bushings are used for short production runs and will not require replacement. They are intended also for short center distances.

Liner Bushings: Liner bushings are provided with and without heads and are permanently installed in a jig to receive the renewable wearing bushings. They are sometimes called "master bushings."

Jig Plate Thickness: The American Standard lengths of jig bushings are based on standardized or uniform jig plate thicknesses of 5/16, ½, ¾, 1, 1⅜, and 1¾ inches.

Jig Grinder. This machine is similar in principle to a jig borer. It is designed primarily to correct the location of holes in hardened-steel parts, jigs, master plates, gage parts, etc. This grinder is especially applicable in making precision, compound, and progressive dies that frequently require holes to be spaced accurately within limits of 0.0005 inch or less.

Jigs and Fixtures. Jigs and fixtures serve the purpose of holding and properly locating a piece of work while it is being machined; they are provided with necessary appliances for guiding, supporting, setting, and gaging the tools in such a manner

that all the work produced in the same jig or fixture will be alike in all respects, even with the employment of unskilled labor. As a general rule, a jig is a special tool, which, while it holds the work, or is held onto the work, also contains guides for the respective tools to be used; whereas a fixture is only holding the work while the cutting tools are performing the operation on the piece, without containing any special arrangements for guiding these tools. The fixture, therefore, must, itself, be securely held or fixed to the machine on which the operation is performed; hence, the name. A fixture, however, may sometimes be provided with a number of gages and stops, although it does not contain any special devices for the guiding of the tools. The definition given, in a general way, would, therefore, classify jigs as special tools used particularly in drilling and boring operations, while fixtures, in particular, would be those special tools used on milling machines, and, in some cases, on planers, shapers, and slotting machines.

Jobbers' Reamer. This style of reamer is similar to a hand reamer, but it is provided with a taper shank so that it may be used for machine reaming. The shank is nearly always a Morse standard taper. Jobbers' reamers are fluted with the same kind of fluting cutters as reamers generally. The clearance is usually ground flat.

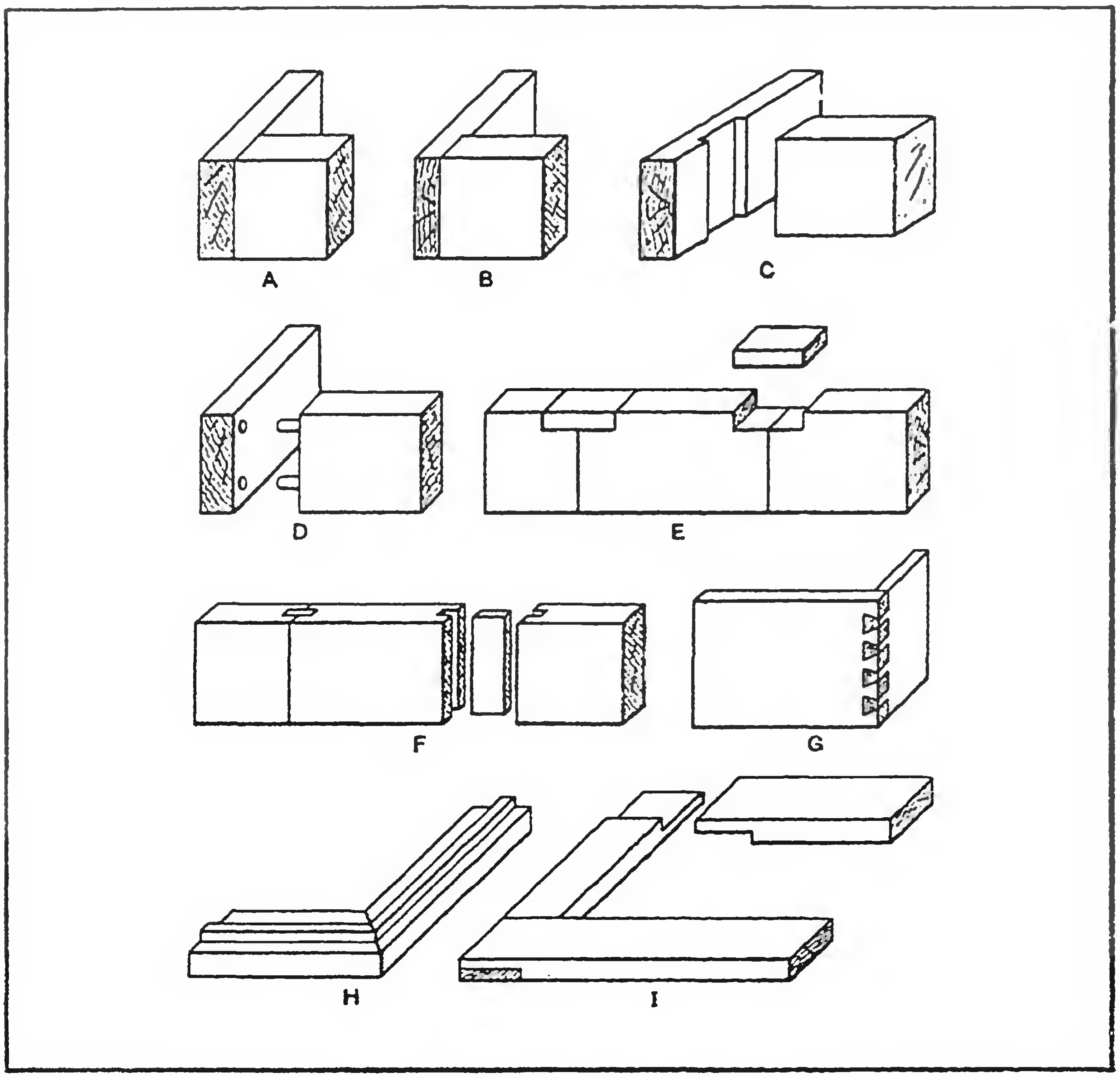
Jointer. The "hand jointer," which is sometimes referred to as a "buzz planer," is used in wood-working shops for jointing and edging stock, the material being pushed by hand across the circular cutters that revolve at a high rate of speed. When in good condition and skilfully used, a plane surface or a straight edge is very easily produced.

Joint Inventors. The term "joint inventors" is one that has been more or less misunderstood, not only by inventors, but also by others interested in patents. A person who furnishes capital only is in no sense a joint inventor, and his interest in the invention and the patent to be obtained therefor should be conveyed by an assignment executed in due form. To make clear the meaning of "joint inventors," suppose one inventor in collaboration with another, devises an engine for automobiles, both working on this particular part of the machine, and one making a suggestion here and the other there, a joint inventorship would exist. On the other hand, if one inventor were to design the motor, and his co-worker the transmission or the differential, there would not be a joint inventorship, for the reason that the motor could operate independently of the particular type of transmission employed, and the transmission could operate independently of the engine.

Joint Patents. Where two or more persons work to perfect an invention, the application must be filed jointly, and the patent is issued in their names. And where two men work to perfect an invention, neither can apply for a patent as sole inventor and obtain a valid patent. Furthermore, the law is well established that where a patent is issued jointly to two or more inventors, either has the right to sell his interest, or manufacture and sell the invention, or license others to do so, without permission from the other inventor.

Joints Used in Patternmaking. The different forms of joints commonly used in the construction of patterns and in many other kinds of wood-working, are shown by the diagrams.

Butted Joint: The butted joint *A* is the simplest form used in wood-working; two pieces are butted or placed one against the other and fastened with nails or screws, the latter giving a stronger joint.



Joints Used in Patternmaking

Rabbeted Joint: The rabbeted joint is used in place of the butted joint when greater strength is required. The end of one piece is cut back or rabbeted, as shown at *B,* to receive the "butt" of the second piece.

Dado Joint: The dado joint *C* is a standard for square and rectangular core-boxes. It prevents the ends from being rammed out or pushed in, and when it is fastened with screws, the box readily parts at the corners.

Doweled Joint: The doweled joint *D* is a butted joint strengthened by dowel-pins.

Reinforced Butted Joint: In making the reinforced butted joint *E,* a portion of each abutting section is cut away to receive a piece that covers the joint and prevents the sections from parting.

Splined or Feathered Joint: The pieces to be joined are grooved to receive a spline or feather (as shown at *F*) which strengthens the joint. This form is used for fastening the arms of wheels and pulleys where they join at the center, and also to secure the joints of rings or flanges that are built of a single course of segments.

Dovetailed Joint: This form of joint (which is shown at *G*) is used principally for holding the corners of beds and light boxes. The angle of the dovetails should be about 15½ degrees.

Mitered Joint: The mitered joint is used for connecting the corners of molding, etc. The angle for cutting is one-half the included angle of the connecting pieces. A 45-degree joint is shown at *H.*

Half-lapped Joint: This joint is used for constructing framework; one-half of each piece is cut away as shown at *I,* so that, when the two sections are fastened together, they will be flush at the joints.

Jominy Hardenability Test. The Jominy hardenability test is a standard method of determining and designating *hardenability* of steel. This test may be used in comparing the hardenability either of successive heats of steel, or of steels of different compositions. The probable hardness of steel for new parts, when production experience is not available, may also be predicted, provided cooling rates occurring during quenching are known.

The Jominy test consists in water-quenching one end of a test bar which is held vertically with the lower end ½ inch above a ½-inch round quenching orifice. The quenching water has a temperature of 40 to 85 degrees F. When the test bar is not in position, this column of water must rise to a free height of 2½ inches above the opening. The test bar (except for shallow-hardening steels) has a diameter of 1 inch and a length

of either 3 or 4 inches, depending upon the method of suspending it vertically in the quenching fixture. All decarburization must be removed from the test bar in machining it to the standard diameter and the bar must be normalized. Preparatory to quenching, the test bar is heated to the specified hardening temperature and held at this temperature for 30 minutes. The heated specimen remains in the fixture for at least 10 minutes, and the surrounding air must be free from currents during cooling. The fixture must be dry at the beginning of each test, and the time between removal of the specimen from the furnace and the beginning of the quench shall not be more than 5 seconds.

Two flats 180 degrees apart are ground not less than 0.015 inch deep along the entire length of the test bar. Then Rockwell C hardness measurements are made at 1/16-inch intervals along these flat surfaces. To illustrate the method of recording the result, assume a test bar hardened above Rockwell C 50 to a distance of 1½ inches (24/16) from the quenched end. The result would be indicated by the marking $J_{50} = 24$. Similarly, a hardness of Rockwell C 30 out 5/16 inch from the end would be designated by $J_{30} = 5$. The last figure in each case equals the distance from the end of the test bar in sixteenths of an inch.

Joule. The unit of work in electrical engineering, as recommended by the International Electrical Congress, in Chicago, 1893, and approved as a legal unit of electrical measure by an Act of Congress, July 12, 1894, is known as the *joule*, which is equal to the energy expended in one second by one ampere against the resistance of one ohm. One joule, expressed in mechanical equivalents, equals 0.7376 foot-pound, or 0.0000002778 kilowatt-hour. Commercially, this unit is too small and, therefore, either the watt-hour, which is 3600 times larger, or the kilowatt-hour, which is 3,600,000 times larger, is used.

Journal. A journal is that part of a shaft or axle which is supported by and revolves in a bearing.

K

Kahle's Cell. This is a primary cell or battery, known as a "standard" cell, used for obtaining a certain standard value of electromotive force under given conditions. In this cell, the positive electrode is amalgamated zinc, and the negative electrode, mercury. A paste of mercurous sulphate and zinc sulphate is placed upon the mercury and acts as a depolarizer. A saturated zinc sulphate solution acts as the electrolyte. The electromotive force of this cell is 1.43 volts at 15 degrees C. (59 degrees F.).

Karmarsch Metal. A bearing metal of the tin-antimony-copper alloy group, containing 70.8 per cent of tin, 19.7 per cent of antimony, and 9.5 per cent of copper is known as Karmarsch metal. Another metal, known by the same name and used for the same purpose, is composed of 71.4 per cent of tin, 7.2 per cent of antimony, and 21.4 per cent of copper.

Keep's Test. A hardness test employing a special apparatus. With this apparatus a standard steel drill is caused to make a definite number of revolutions, while it is pressed with standard force against the specimen to be tested. The hardness is automatically recorded on a diagram on which a dead soft material gives a horizontal line, while a material as hard as the drill itself gives a vertical line, intermediate hardness being represented by the corresponding angle between 0 and 90 degrees.

Kelsanite. Non-inflammable liquid, which can be applied to metal parts by brushing, spraying, or dipping. Protects surface from corrosion or dirt, as it is both waterproof and air-tight. Coating has high adhesive qualities, but does not vulcanize to surfaces on which it is applied. After the coating has served its purpose, it can be stripped off like a cellophane wrapper.

Kelvin, Degrees. Degrees Kelvin (absolute temperature scale) equal degrees Centigrade plus 273,16.

Kelvin's Law. Kelvin's law relates to the most economical size of conductors for transmitting electric power. It is as follows: The most economical area of a conductor is that for which the annual interest on the capital outlay equals the annual cost on the energy loss in the conductors.

Kem Bakolescent and Kem Plastite. An enamel applicable to plastic surfaces. Available in iridescent form (Kem Bakolescent) or in solid colors (Kem Plastite). Applied by either dipping or spraying. Useful in dressing up molded parts for vacuum cleaners, electrical wiring devices, radio cabinets, automobile parts, etc.

Kennametal. This is the trade name for a series of cemented carbide compositions having a high degree of hardness and strength. These cemented carbides are especially applicable to various forms of metal-cutting tools and miscellaneous parts or inserts which must be highly resistant to wear. The effective ingredient of these compositions for steel cutting is tungsten-titanium carbide. The hard crystals, together with cobalt, carburized tungsten and other ingredients, are cemented by processes of powdered metallurgy in special electric vacuum furnaces to form carbide blanks.

Kennedy Key. The Kennedy or double key system is used in rolling mills and is adapted to the transmission of heavy loads, especially where the torque is intermittent and the direction of rotation periodically reversed. Each key is so located that a diagonal line passing through two corners of the key approximately intersects the shaft axis. The keys have a taper of 1/8 inch per foot on the hub side and the sides fit closely between the shaft and hub. The keys are driven in from opposite sides of the hub.

Kerosene. A refined petroleum distillate having a flash point not below 73° F. (23° C.), as determined by the Abel Tester (which is approximately equivalent to 73° F. (23° C.) as determined by the Tag Closed Tester) and suitable for use as an illuminant when burned in a wick lamp. Note.—In the United States of America local ordinances or insurance regulations require flash points higher than 73° F. (23° C.), Tag Closed Tester.

Kerosene Lubrication. Kerosene has proved effective as a lubricant for the plain bearings of grinding wheel spindles. The following information is based upon the experience of the Norton Co. This type of lubrication is recommended only for plain bearings to which an ample flow of lubricant is delivered. It is not recommended for drip-lubricated bearings. The spindle journals of machines intended for kerosene lubrication are finished by methods that give them a highly reflective mirror-like surface. The surfaces thus finished are accurate in size and straightness to 0.0001 inch, and show readings from 1 to 2 micro-inches on the Profilometer.

While kerosene has been used for many years as a spindle lubricant in the high-speed internal spindles supplied with Norton tool and cutter grinders, a high-quality oil with a Saybolt viscosity

rating of from 60 to 185 at 100 degrees F. has previously been employed for the spindles of external grinders which operate at speeds ranging from about 800 to 1800 R.P.M., depending on the grinding wheel diameter. From 0.001 to 0.002 inch clearance for oil was provided in the bearings, and a bearing temperature of about 140 degrees F. was considered normal. With kerosene lubrication, these clearances can be safely reduced to approximately one-fifth of that formerly provided, and the temperature of the bearing will not rise much, if any, above 100 degrees F. The kerosene temperature does not rise above 100 degrees F. and with kerosene lubrication the fluctuations in temperature are very slight. Consequently, the repetitive expansion and contraction changes of the grinding wheel unit elements are greatly reduced.

Kewanee Union. The Kewanee pipe union has one pipe end of brass and the other of malleable iron, with a ring or nut of malleable iron. The arrangement and finish of the several parts is such as to provide a non-corrosive ball-and-socket joint at the junction of the pipe ends, and a non-corrosive connection between the ring and brass pipe end.

Key. A key of the type commonly used in machine construction consists ordinarily of a piece of steel, either square or rectangular in cross-section, which is inserted into a keyway or keyseat formed partly in a shaft and partly in the hub of a gear, pulley, or other part which, by means of the key, is driven positively and prevented from rotating relative to its shaft. While keys are used primarily to prevent relative rotation between shafts and such parts as pulleys, gears, etc., they also prevent axial movement in many cases, owing to the frictional resistance between the keyed parts. The type of key that may properly be employed in any case naturally depends somewhat upon the class of work for which it is intended.

The *sunk key* is the most common type. This is of rectangular section and engages a groove or slot formed both in the shaft and hub of the gear or pulley. The so-called *saddle key* does not enter a slot in the shaft, but is curved on the under side and is slightly tapered on top so that when driven into place the shaft is gripped by the frictional resistance. The *flat key* is a rectangular shape which bears upon a flat surface formed on one side of the shaft. The draw or *gib key* is a sunk key which has a head by means of which it can be removed. The *round tapered key* is simply a taper pin which is driven into a hole that is partly in the shaft and partly in the hub; this form is used for light work. The name *feather* or *spline* is applied to a key which is fixed to either a shaft or hub, as when a gear must be driven

by a shaft, but at the same time be free to slide in a lengthwise direction. The *Woodruff key* is a section of a disk, the part which enters the shaft being circular.

The width of an ordinary sunk key ordinarily is equal to about one-fourth of the shaft diameter and the thickness, when a flat key is preferred to the square form, is usually about one-sixth of the shaft diameter; these proportions are varied somewhat by different manufacturers. The taper of American Standard square and flat keys is 1/8 inch per foot.

Keyseating Machines. The machines which are designed especially for cutting keyseats or keyways in the hubs of pulleys, gears, etc., are generally known as *keyseaters*. Machines of this class usually have a base or frame which contains mechanism for imparting a reciprocating motion to a cutter bar, which moves vertically for cutting a keyseat in the work. There are several types of machines which are used for internal keyseating operations in addition to the machines designed especially for this work. Broaching machines as well as slotters are commonly used, and keyseating is also done to some extent in shapers and planers.

Kilogram-Calorie. A kilogram-calorie, frequently simply termed "calorie," is a thermal unit based on the metric system, designating the amount of heat required for raising the temperature of one kilogram of pure water one degree C. One kilogram-calorie = 3.968 British thermal units = 1000 gram calories.

Kilogram-Meter. This is a unit of work in the metric system, designating the work done in raising one kilogram to a height of one meter. One kilogram-meter = 7.233 foot-pounds.

Kilogram Per Square Centimeter. This is a unit in the metric system for measuring pressure. One kilogram per square centimeter = 14.223 pounds per square inch.

Kilogram Per Square Millimeter. This is a unit in the metric system for measuring pressure. One kilogram per square millimeter = 1422.32 pounds per square inch.

Kilovolt-Ampere. The term *kilovolt-ampere* (kva.), equal to 1000 volt-amperes, is used to express the *apparent power* in a reactive circuit, i.e., the product of the effective values of the current and the voltage, IE, in a reactive circuit. The term "kilowatt" (kw.), equal to 1000 watts, on the other hand, expresses the *true power*, IE $\times$ cos θ in a reactive circuit, and is the reading obtained by a wattmeter applied to the circuit. The ratio of the watts to the volt-amperes is called the *power factor*. For example, assume an alternating-current generator supplying a load of 800 kilowatts, the power factor of which is 80 per cent. The true rating of such a generator, or the one on which the capacity of the prime mover should be based, would be 800 kilo-

watts, while the apparent rating of the generator would be $\frac{800}{0.80}$ $=$ 1000 kilovolt-amperes. To avoid any misunderstanding, the rating usually appears as follows: 1000 kva. (800 kw., 0.8 power factor). For direct-current generators, however, the rating is always given in kilowatts, because these machines always operate on non-inductive load, the true power is equal to IE and no power factor is involved. The rating of a synchronous machine is usually determined by its permissible temperature rise caused by the currents in the armature and the field windings. This rise increases with increasing load and with decreasing power factor. Thus for a given kilovolt-ampere output, the total heat losses are larger for low than for high power factors, the difference being due to the heat generated by the increased field current which is required to overcome the armature reaction and maintain the given current and terminal voltage.

Kilowatt. The unit of power generally adopted for all electrical work and also frequently used in mechanical engineering is known as the "kilowatt." One kilowatt equals 1.34 horsepower, or one horsepower equals 0.746 kilowatt. The latter figure is the exact standard relationship between the kilowatt and the horsepower used by the United States Bureau of Standards, and may, therefore, be assumed as the exact equivalent of horsepower in electrical units. An effort has been made in scientific and engineering circles to substitute the kilowatt for the indefinite horsepower as the unit measurement of power. The kilowatt is just as good a mechanical unit as an electrical one, and it has the advantage of being a logical rating expressing a definite relation to the absolute system of measurements in general use for scientific purposes. One of the advantages of the kilowatt is that it is an absolute international unit which is not true of the horsepower. The latter, in countries using the metric system, is calculated as the equivalent of 75 kilogram-meters per second, which equals 542.5 foot-pounds per second, or 32,550 foot-pounds per minute—an appreciable amount less than the 33,000 foot-pounds constituting the British and American horsepower. The adoption of the kilowatt as a unit of power would avoid having generators rated in kilowatts while their driving machinery and electric motors are rated in horsepower.

Kilowatt-Hour. A unit of work or energy equivalent to one kilowatt acting one hour. 1 kilowatt hour $=$ 1000 watt-hours $=$ 1.34 horsepower-hour $=$ 2,655,200 foot-pounds $=$ 3,600,000 joules $=$ 3415 B.T.U. $=$ 3.54 pounds of water evaporated at 212° F. $=$ 22.8 pounds of water raised from 62° to 212° F.

Kinematics. A branch of mechanics that deals with relative motions of bodies.

Kinetic Energy. Energy, in mechanics, is defined as the capacity of a body for performing work and is measured in foot-pounds. It may be either *potential*, as in the case of a body of water stored in a reservoir, which is capable of doing work by means of a water turbine if released, or *kinetic*, which is the energy of a moving body. The kinetic energy of a moving body is the work which the body is capable of performing against a resistance before it is brought to rest. The kinetic energy of any moving body is equal to the work which has brought it from its state of rest to its actual velocity. The measure of the kinetic energy is the product of the weight of the body multiplied by the height from which it must fall to acquire its actual velocity; hence, if $V =$ velocity in feet per second; $W =$ weight of the body; $g =$ acceleration due to gravity $= 32.2$; then, the kinetic energy E, in foot-pounds, equals:

$$E = \frac{WV^2}{2g}.$$

In a rotating body, the kinetic energy may be found by the same formula, if V is the velocity of the center of gyration.

Kinite. Kinite is the trade name for an alloy steel containing chromium and cobalt, but no tungsten, and has been found especially adapted for making dies requiring great resistance to abrasion or wear. Trimming dies for hot forgings, for example, are among the tools for which the material is well suited. Furthermore, the material is practically non-corrosive, and has been found excellent for the making of glass and other molds requiring a high heat-resisting material.

Kirchhoff's Laws. Kirchhoff's first law is as follows: In any closed circuit, the algebraic sum of the electromotive forces, in volts, will be equal to the algebraic sums of the currents in the conductors multiplied respectively by the resistances of the conductors through which they flow. In other words, all the electric forces in the circuit are balanced. Kirchhoff's second law is as follows: If any number of wires converge at a point, the sum of the currents flowing toward the point will be just equal to the sum of the currents flowing away from the point; or, in other words, the currents must balance.

Kirksite. This is a zinc-base alloy, in both cast and rolled forms, that is especially useful in the aircraft or other industries for making low-cast sheet metal forming, blanking and trimming dies. Even large forming or cutting dies may be made readily. Forming dies are cast to shape and little or no machining or hand work is required. Kirksite can be remelted repeatedly. It is not intended to replace steel or cast-iron dies but is for use when the total production or manufacturing conditions

justify a low-cost die construction. Melting point, 717 degrees F., tensile strength, 37,800 pounds per square inch sand cast, and 62,000 rolled. Rolled Kirksite is applied to blanking or trimming dies.

Kish. The name "kish" is sometimes given in metallurgy to the carbon or graphite which appears on the surface of the iron in a blast furnace during the process of tapping. It is also used to designate the carbon which segregates in the form of plates in cast iron during the solidification.

Knife-Edge Bearings. So-called "knife-edge" bearings are used on weighing and testing machines. When the knife-edge bearing as well as the seat are made of the proper material, the knife-edge will sustain loads up to 10,000 pounds per inch of length; but ordinarily about 5000 pounds is the usual limit of pressure. The knife-edge, as well as the seat bearing upon it, should be made from tool steel having a carbon content of from 0.9 to 1 per cent. The knife-edge should be properly supported underneath its whole length in order to prevent deflection. The angle of the knife-edge should be 90 degrees for heavy loads. It should have a very slight flat at the extreme point, so small, however, that it is barely visible, because a pronounced flat or radius at the edge decreases the accuracy of the device. This flat may be obtained by rubbing with an oilstone. The seat against which the knife-edge bears, if made of an angular form, should be provided with a small round at the vertex of the angle.

Knife File. Files of this class derive their name from the fact that they resemble somewhat the blade of a knife. The section is tapering toward one edge and in a lengthwise direction toward the point. The teeth are double-cut, mostly bastard; this type is used for many purposes to which the knife shape is adapted.

Knoop Hardness Test. The Knoop hardness test is applicable to extremely thin metal, plated surfaces, exceptionally hard and brittle materials, very shallow carburized or nitrided surfaces, or whenever the applied load must be kept below 3600 grams. The Knoop indentor is a diamond ground to an elongated pyramidal form and it produces an indentation having long and short diagonals with a ratio of approximately 7 to 1. The longitudinal angle of the indentor is 172 degrees 30 minutes and the transverse angle 130 degrees. The Tukon Tester in which the Knoop indentor is used is fully automatic under electronic control. The Knoop hardness number equals load in kilograms divided by the projected area of indentation in square millimeters. The indentation number corresponding to the long diagonal and for a given load, may be determined from a table

computed for a theoretically perfect indentor. The load, which may be varied from 25 to 3600 grams, is applied for a definite period and always normal to the surface tested. Lapped plane surfaces free from scratches are required.

Knuckle-Joint Embossing Press. Knuckle-joint power presses are used extensively for embossing coins, medallions, and other intricate forms, as well as for lettering or embossing that requires a large amount of pressure for a comparatively short time. Because of their use for this class of work these presses are often termed "coining" presses. In the knuckle-joint embossing press, the slide is operated by two knuckle arms. As the knuckle arms are straightened, the vertical movement of the slide is small, compared with the horizontal movement of the knuckle. It is this slow increasing pressure that distinguishes the knuckle-joint press from other types. Such a pressure enables the metal to flow under the force of the punch, and fine intricate embossing is possible.

Knurling. The forming of a series of fine ridges upon the periphery of a circular part, such as a screw-head, handle, or knob, is known as *knurling* or *nurling*. The purpose of this checked or milled surface is usually to increase the grip of the hand and thus facilitate rotating the knurled part, although knurling is also done in many cases merely to produce an ornamental effect. The handles of gages and other tools are often knurled, and the round thumb-screws used on instruments, etc., usually have knurled edges. A knurling tool has a hardened disk or a set of disks mounted in a holder; when knurling, one or two of these disks (the number depending upon the type of knurling tool used) are pressed against the unhardened work, and rotate with it, thus reproducing upon the work the knurling which has been formed upon the periphery of the knurl itself. A common type of knurling tool is equipped with two knurls having teeth or ridges which incline to the right on one knurl and to the left on the opposite knurl. When these two knurls are pressed against the work as the latter revolves, one knurl forms a series of left-hand ridges and the other knurl right-hand ridges, which cross and form a diamond-shaped knurling. Knurling is done in the lathe either by a hand-controlled tool or by a tool which is held in the toolpost the same as for turning.

Koroseal. A rubber-substance that does not swell when exposed to many oils and greases nor disintegrate in the presence of corrosive chemicals. It will resist the action of chromic acid and hot concentrated nitric acid and can be molded to any shape.

Koroseal-Coated Paper. A paper coated with a thin layer of Koroseal, a rubber-like substance impervious to deteriorating fluids and gases. The coated paper is resistant to acid, oil, water, air, and light. Offers protection for exposed surfaces of machinery while in ocean transit, since coverings can be made from it which will exclude the salt sea air.

Kovar. An alloy having a thermal expansion that permits permanent sealing of the metal to glass. It is unaffected by mercury and mercury vapors. Used in the electrical industry for sealing of metal to glass, as in electronic tubes, etc.

Krypton. Krypton is a gaseous chemical element, the symbol of which is Kr, atomic number 36, and atomic weight, 83.7. It is present in the atmosphere to the extent of one volume in 20,000,000 volumes of air. It is a colorless, transparent gas which becomes liquid at —157 degrees C. (—251 degrees F.) and solidifies at —169 degrees C. (—272 degrees F.). It was first discovered in 1898.

Kyanizing. Kyanizing is a treatment applied to wood to render it proof against decay, by saturating it with a solution of corrosive sublimate (mercuric chloride, $HgCl_2$). The saturating is done either in open tanks or under pressure in closed tanks.

L

Lacquer. Lacquer is the general name used for colored and frequently opaque varnishes used for applying a protective finish to metallic objects. Lacquer is applied to polished metal surfaces, such as brass, pewter, and tin, in order to give them a golden, bronze-like, or other lustrous surface. The main constituents of lacquer are shellac and alcohol, to which are added a number of other substances to give the required tint.

Lag Angle. When two sinusoidal quantities, such as alternating current or voltage, have the same period but are displaced in phase, the angle of lag of the first quantity with respect to the second is the angular phase difference by which the second quantity must be assumed to be retarded to coincide with the first quantity.

Lag Screw. A large form of wood-screw having a square head (instead of the slotted form) so that it can be turned with a wrench. (See Wood-screws.)

Lame's Formula. Lame's formula is the generally accepted formula for calculating the strength of cylinders subjected to high internal pressure. By means of this formula, the thickness of the metal of the cylinder can be determined when the inside radius, the maximum allowable fiber stress per square inch, and the pressure within the cylinder in pounds per square inch, are known. It is one of the more important engineering formulas, and will be found in engineering handbooks.

Lamp Base and Socket Shell Threads. The "American Standard" threads for lamp base and socket shells are sponsored by the American Society of Mechanical Engineers, the National Electrical Manufacturers' Association and by most of the large manufacturers of products requiring rolled threads on sheet metal shells or parts, such as lamp bases, fuse plugs, attachment plugs, etc. There are five sizes, designated as the "miniature size," the "candelabra size," the "intermediate size," the "medium size" and the "mogul size." For table of dimensions see MACHINERY'S Handbook.

Lampblack. Lampblack is made by burning oils and is a very pure form of carbon. It has a specific gravity of 1.82, grinds in 75 per cent of oil, and has unusual tinting power, and is, therefore, used in large quantities for this purpose. Other characteristics are its great stability, its very slow rate of drying, and

a preserving action on the oil with which it is combined. It resembles graphite in its property as a conductor of electricity.

Lancashire Process. The Lancashire process for producing wrought iron consists in melting pig iron between two layers of charcoal, the molten metal collecting in a pasty mass at the bottom of the furnace. In dropping to the bottom of the furnace, the molten iron passes through an air blast and is decarburized. The molten mass is permitted to remain at the bottom of the furnace for from 20 to 25 minutes, after which it is mixed with slag, remelted, and, while in a pasty state, formed into balls, removed from the furnace, and hammered or rolled. The process resembles the so-called "Walloon" process.

Land. The term "land" as applied to metal-cutting tools such as taps, reamers, milling cutters, etc., refers to the top surface of a tooth. In the case of a tap, the land is the surface between two flutes, the land width being measured along the outer circumference from the front face of the tooth to the heel. The land of a reamer or milling cutter tooth is the top or clearance surface back of the cutting edge, but does not include the steeper slope at the rear which forms the back of the tooth and part of the flute or chip clearance space.

"Lands" of Gearing. The *bottom land* is the surface of the gear body between adjacent teeth. The *top land* is the surface of the tooth which is farthest from its supporting body.

Lang's Lay Rope. In the regular type of wire rope, the wires of the strands are twisted in one direction and the strands themselves are laid into the rope in the other direction. In the Lang's lay rope, both the wires in the strands and the strands in the rope are twisted in the same direction. Such a rope is more easily untwisted than one made in the ordinary or "regular-lay" manner, and it is more difficult to tuck the strands securely in a splice, but the Lang's lay rope is, nevertheless, used to some extent, because it resists external wear and grip action much better than the regular-lay rope. This type of rope, however, should not be used unless assurance has been given by the rope manufacturers that it is adapted for the service for which it is intended. No universal rule can be given regarding its application, but its use is limited as compared with the regular-lay rope.

Lantern Pinions. Lantern pinions are formed of two disks between which are "rounds" of steel wire or rod to serve as teeth or "leaves." This type of pinion has been used extensively in clock mechanisms, and formerly was employed in connection with primitive millwright work. Lantern pinions are not adapted to driving, and in clock mechanisms they are the driven members.

An accumulation of dirt that would stop the action of an ordinary cut pinion is simply pushed through between the rounds of a lantern pinion, which, therefore, continues to function. This is an important advantage of this type of pinion as applied particularly to low-priced clocks which frequently operate under unfavorable conditions.

Lap, Diamond. See Diamond Lap.

Lapping. Lapping is a refined abrading process generally employed for correcting errors in hardened steel parts and securing a smooth surface, or for reducing the size a very small amount. The lap is made of some soft metal, such as cast iron or brass, and it is "charged" with an abrasive which is imbedded into its surface. The grade or coarseness of the abrasive depends upon the finish required and the amount that must be removed by lapping. The form of the lap naturally depends upon the shape, size, and location of the surfaces upon which it is used.

Lapping Machines. There are several types of lapping machines. One special design used for lapping precision gage blocks has two flat laps of circular form. The lower lap is attached to the base of the machine, and the upper lap is secured to an arm by a connection which permits the lap to move freely in any direction but not to revolve. This arm is pivoted at one end so that the upper lap can be swung to one side to expose the lower lap and the work. When a machine is in use, one lap is above the other, and the gage blocks are between them, so that both the upper and lower surfaces of the blocks are lapped simultaneously. When the blocks are to be removed or inserted in the machine, the upper lap is swung out of the way. Between these two cast-iron laps, there is a steel plate or "spider" which contains holes into which the blocks to be lapped are inserted. The upper and lower laps remain stationary, while the spider receives a planetary motion which brings each block into contact with the entire surface of each lap.

Lapping Machine for Cylindrical Parts: A machine designed for lapping cylindrical parts is equipped with two lapping wheels between which there is a spider for holding a number of pins in position. In operation, the upper lap is lowered on the parts to be lapped, and the variation in the lapping wheel speeds causes the parts to rotate and creep slowly in a circular path. There are, in fact, three movements which insure accurate results.

Lard Oil Compounds. Lard oil compounds for use as cutting lubricants, should be stable blends of lard oil with other oils which will give to the compound the properties undiluted lard oil lacks. The diluent must be a liquid (rather, an oil) which can be added

to the lard oil in any proportion that experience shows to be the most effective for the particular work the compound is to perform.

The source of such diluents is the petroleums, the mineral oil distillates of which can be obtained in numerous varieties. The proportions of mineral and lard oils vary, of course, as does also the viscosity of the mineral oil constituent, depending upon the nature and the severity of the work to be done. The mineral oil may be one of the pale amber mineral oils of medium viscosity, as used in the lard oil compounds suitable for high-speed operations, where a constant and abundant stream of cutting oil is required, or it may be a heavy-bodied viscous oil which is compounded with the lard oil for use in heavy, coarse work.

Classification of lard oil compounds has been carried out by certain leading producers of cutting lubricants. For instance, there are lard oil compounds designated by number, the number indicating the percentage of lard oil contained in the compound. With such an index as a guide, and the nature of the work to be performed known, a lard oil compound may be selected for any particular operation, embodying the qualities that experience has shown to be required.

Latent Heat. Latent heat is the heat which disappears when a solid is changed to a liquid, or a liquid to a gas, the former being called the *latent heat of fusion*, and the latter, the *latent heat of evaporation*. The heat which disappears in this manner is converted into mechanical work, and is used in tearing apart the molecules, and, hence, produces no change in the temperature of the substance. When the gas changes back to a liquid, or the liquid to a solid, the latent heat is again given out. The action described may be illustrated by the melting of ice into water, and the evaporation of the water into steam. When heat is applied to a piece of ice in an open vessel, it gradually melts, but the temperature of the water remains at 32 degrees until all of the ice has been melted, the heat having been used in the process of changing the ice into water. If heat is still applied, the temperature of the water will rise until it reaches 212 degrees F., at which point evaporation takes place, and although heat is constantly applied, the temperature of the water remains constant until it is all evaporated into steam. If the steam were collected and condensed, and the water cooled to 32 degrees F. and frozen, all of the heat which had been supplied would again be given out. Latent heat plays an important part in the operation of a boiler and the generation of steam. When it is said that the latent heat of evaporation of water is 966.6, this means that it takes 966.6 heat units to evaporate one pound of water after it has been raised to the boiling point, 212 degrees F.

Lathe Center Point Angle. In the United States the standard included angle for the work-supporting ends of lathe centers is 60 degrees. This angle is increased to 75 degrees for some axle turning or other heavy-duty lathes. British standard lathe centers have an angle of either 60 or 75 degrees as specified by the purchaser. For lathes engaged in turning axles for railway rolling stock, the angle of 75 degrees has been adopted by the British Railway Companies.

Lathe Classification. As lathes in general are used for a great variety of operations, naturally there are many different designs and sizes. The various types are usually classified, either with respect to some characteristic constructional feature, or with reference to the general class of work for which the lathe was designed. The most common type of lathe is usually known by manufacturers as an *engine lathe.* The term "engine," as used in this connection, simply means a machine, and it serves to designate that particular class of lathe which is hand manipulated and used by machinists for general work. In ordinary shop usage, the word "lathe" is commonly used to indicate a lathe of this class. Lathes having gears which are changed for cutting threads of different pitch are sometimes known as *plain* or *standard* engine lathes, whereas those having a gear-box by means of which the necessary gear combination may be obtained by simply shifting one or two levers are usually known as the "quick change-gear" type. The *tool-room* or *toolmaker's* lathe is classified according to the general class of work for which the lathe is designed. It is similar in appearance to an ordinary engine lathe, but has extra attachments and is generally considered a very accurate machine.

Other types of lathes which have some distinguishing characteristic are: The *turret lathe,* which is so named because tools for performing successive operations are held in a revolvable turret; the *bench lathe,* which is so small that it is mounted on a bench, and intended for delicate work usually requiring considerable accuracy; the *precision lathe,* which is usually a bench type that is capable of very accurate work and is more expensive than an ordinary bench lathe; the *gap lathe,* which has a gap formed in the bed in front of the faceplate in order to increase the "swing" or maximum diameter that may be revolved; the *extension gap lathe,* which has a double form of bed, the upper section of which may be extended in order to form a gap for increasing the swing, and also the distance between the centers; the *crankshaft lathe,* which is especially arranged for turning crankshafts: the *wheel lathe,* which is a large design intended especially for turning locomotive driving wheels; the *axle lathe,* which is a powerful design for turning car axles; the *foot-power lathe,*

which is driven by a foot-treadle and is intended for small work; the *speed lathe,* which is without back-gears and is used for rotating parts rapidly for polishing, hand turning, or filing; the *chucking lathe,* which is especially adapted for parts that must be held in a chuck while being operated upon; and the *automatic lathe,* which is designed for the duplicate production. See Automatic Lathe; Bench Lathe; Blanchard Lathe; Burnishing Lathe: Capstan Lathe; Turret Lathes; T-Lathe.

Lathe Size. The size of an engine lathe, according to the practice followed in the United States, is based upon the "swing" or the maximum diameter that can be rotated over the ways or shears of the bed. The nominal sizes listed by lathe manufacturers, however, ordinarily do not represent the maximum swing, but a diameter which is somewhat less. For instance, a lathe which is listed as a 24-inch size may actually swing 24½ or 25 inches. The variations between the nominal and actual sizes range from about ½ to ¾ inch up to 1½, or even 2 inches. According to the English practice, the size of a lathe is defined by the height of the centers above the top of the bed.

Lathe Tools, Right- and Left-Hand. The tools used on lathes may be either right-hand or left-hand, depending upon the location of the cutting end. According to common usage, lathe tools are classed as "right-hand" when the tool is adapted for cutting from right to left, the cutting edge being on the left-hand side as the tool is seen from above. Thus, a right-hand side tool, for example, is adapted for facing the right-hand side of a collar or the right-hand end of a shaft, and vice versa for left-hand side tools. The "hand" of a lathe tool, therefore, seems to be related to the location of the surfaces the tool is adapted for cutting, rather than to the position of the cutting edge, since a right-hand tool has its edge on the left-hand side, as seen from the top, and the the reverse is true for a left-hand side tool. See also Planer Tools, Right- and Left-hand.

Latimer-Clark Cell. This is a primary cell or battery having a zinc anode, a mercury cathode, a zinc sulphate electrolyte, and a paste of mercurous sulphate and zinc sulphate for a depolarizer. This is a so-called "standard cell" producing 1.43 volts at 15 degrees C.

Latten Alloy. Latten is an alloy of copper and zinc, and belongs, therefore, to the class of alloys generally known as brasses. Latten is made in thin sheets and used especially for monumental brasses and figures. It is made in three commercial forms: black latten, which is rolled but unpolished; shaven latten, which is unpolished, but of extreme thinness; and rolled latten, which may be similar to either black or shaven latten in thickness, but which has both sides polished.

Lavite. "Lavite" is a trade name for certain salt baths used in heat-treating steel. These salt-bath heating mediums may be used for a wide range of temperatures, varying from 500 degrees F. for tempering up to 2300 degrees F. for heating high-speed steel for hardening. A Lavite bath transmits heat to steel in a manner quite different from a lead bath or an oven furnace. When the steel is introduced into a bath of carbon steel Lavite, which has a melting point of 1300 degrees F., the Lavite freezes around the steel, and forms an insulating jacket which prevents too rapid transfer of heat in the initial stages of the heating period. This jacket is also slow in melting, and the composition of "Lavite" is such that the melting of the jacket proceeds at a rate that permits of a uniform transmission of heat to the metal. The high specific heat of "Lavite" and its high heat of fusion account for the slow rate at which the insulating jacket melts. When the temperature of the steel has reached 1300 degrees F., the jacket has entirely disappeared, and at this point also, there is a favorable condition for heat transfer, because the temperature difference between the steel and the bath is comparatively small. Beyond 1300 degrees F., the full heating effect of the bath is obtained, and this effect is enhanced by the low viscosity of the salt bath, which permits free circulation of the heated salt around the steel.

With lead, no insulating jacket—or at best a very thin jacket—is formed.

Law of Charles. See Charles' Law.

Law of Conservation of Mass. This is a chemical law, applying to all chemical reactions, which states that whenever a change in the composition of substances takes place, the amount of matter after the change is the same as before the change.

Law of Multiple Proportion. Same as Dalton's law.

Law of Sines and Cosines. In a triangle, any side is to any other side as the sine of the angle opposite the first side is to the sine of the angle opposite the other side; or, if a and b be the sides, and A and B the angles opposite them:

$$\frac{a}{b} = \frac{\sin A}{\sin B}.$$

In a triangle, the square of any side is equal to the sum of the squares of the other two sides minus twice their product times the cosine of the included angle; or if a, b, and c be the sides and the angle opposite side a be denoted A, then:

$$a^2 = b^2 + c^2 - 2bc \cos A$$

and

$$a = \sqrt{b^2 + c^2 - 2bc \cos A}.$$

These two laws, together with the proposition that the sum of the three angles equals 180 degrees, are the basis of all formulas relating to the solution of triangles.

Lay. See Surface Finish.

Laying-Out Plate. Surface plates are sometimes formed of large castings which are mounted on a special bed. Large plates of this kind are commonly used to provide a flat surface for laying out machine parts rather than for testing the accuracy of flat surfaces and they are commonly known as laying-out plates.

Lay of Wire Rope. The lay of wire rope is the distance parallel to the axis of the rope in which a strand makes one complete turn about the axis of the rope. The lay of the strand, similarly, is the distance in which a wire makes one complete turn about the axis of the strand. According to U. S. Government specifications, wire rope shall be regular lay; that is, the strands shall form a helix about the axis of the rope similar to the threads of a right-hand screw and the wires form a left-hand helix about the axis of the strand. The lay of the wires in the strand should make them approximately parallel to the axis of the rope where they would come into contact with a cylindrical surface which inclosed the rope. Seizing strand shall be standard lay; that is, the wires shall form a helix about the axis of the strand similar to the threads of a left-hand screw. The lay of wire rope shall be obtained by measuring, parallel to the axis of the rope, the distance in which a strand makes five or more complete turns around the rope. This distance divided by the number of turns is the lay of the rope. When measuring the lay, there shall be no axial load on the rope, and the measured distance shall not be within 10 feet of the end of the rope.

Laytex. A high-flexible, high-strength, compression-resistant rubber with a high dielectric strength. It has a stretch of 750 per cent and a tensile strength of 5000 pounds per square inch and is especially suitable as an electrical insulation material, both because of its high dielectric strength and because it is not susceptible to moisture.

Lead and Its Properties. Lead rarely occurs free in nature, and then only in minute quantities, but it is found abundantly in combination with other elements. Its strength in both compression and tension is very small, so that it cannot be drawn into fine wire, although it can be rolled into very thin sheets. The most important lead mines are in Nevada and Colorado, and in England, Wales, Germany, Spain, Mexico, and Brazil. As lead unites readily with almost all other metals, it is used in many

alloys for bearing metals, electrotype metal, type metal, "white metal," etc. Alloys composed of lead, bismuth, and tin are noted for their low melting points. The chief uses for lead, except in alloys, are for service pipes in water piping, as a base for a number of paints, and for shot and bullets. Lead is easily dissolved in nitric acid; it is dissolved in acetic acid only when in contact with air; and is scarcely affected by sulphuric acid lower than 66 degrees Baume. Hydrochloric acid attacks it very slowly, because of the layer of insoluble chloride formed. The chemical symbol of lead is Pb; atomic weight, 207.1; melting point, 327 degrees C. (621 degrees F.); linear expansion per unit of length, per degree F., 0.0000157; specific heat, 0.031; and conductivity for both heat and electricity (silver = 100), 8.5. The ultimate tensile strength of cast lead is about 2000 pounds per square inch; and the ultimate tensile strength of lead pipe, about 2200 pounds per square inch. The specific gravity of lead varies from 11.35 to 11.37, and, hence, its weight per cubic inch equals 0.41 pound. It vaporizes at a bright-red heat and burns at from 1480 to 1540 degrees C. (about from 2700 to 2800 degrees F.).

Lead in Bearings: Lead flows more easily under pressure than any of the common metals, and it has great anti-frictional properties. A number of metals exceed lead in this property, but their cost or some other factor renders them unavailable. As the amount of lead that is used in a given bearing is increased, the lower the frictional resistance; the bearing also becomes softer and less expensive. Lead, however, is too soft to be used alone, as it cannot be retained in the recesses of the bearing even when used simply as a liner and run into a shell of brass, bronze, gun-metal, or some other alloy. Hence, various other metals are alloyed with it, such as tin, antimony, copper, zinc, iron, and a number of nonmetallic compounds, such as sodium, phosphorus, and carbon. If antimony is added to lead, the hardness and brittleness is increased and if tin is added as well, it makes a tougher alloy than lead or antimony alone. Nearly all of the various babbitt metals are alloys of lead, tin, and antimony in various proportions, with or without other ingredients. In such babbitts, the wear increases with the amount of antimony and the price with the amount of tin. The higher antimony babbitts are used in heavy machinery, as they are harder, while those low in antimony are used in high-speed machinery.

Lead Angle. When two sinusoidal quantities, such as alternating current or voltage, have the same period but are displaced in phase, the angle of lead of first quantity with respect to the second is the angular phase difference by which the second quantity must be assumed to be advanced to coincide with the first quantity.

Lead Angle of Screw Thread. The helix angle of a screw thread, according to customary practice, is not measured relative to the axis but from a plane perpendicular to the axis, and it is known as the "lead angle." The helix angle of a helical gear is measured from the axis. The helix angle in each case and for any given diameter of screw thread or gear, depends upon the lead of the thread or gear tooth. The term "lead angle," however, is applied only to screw threads, worms, etc., to indicate that the angle is measured from a plane perpendicular to the axis. This angle is more useful in connection with screw threads, and the angle relative to the axis is more useful in designing helical gears.

Lead Angle of Turning Tool. The term "lead angle" is sometimes applied to the angle of the side or leading cutting edge of a turning tool. The angle thus designated is the same as the one known as "side cutting-edge angle" in the American Standard for single-point tools.

Lead Baths. The lead bath is extensively used in connection with the heat-treatment of steel, but is not adapted to the high temperatures required for hardening high-speed steel, as it begins to vaporize at about 1190 degrees F., and, if heated much above that point, rapidly volatilizes and gives off poisonous vapors. Lead furnaces should be equipped with hoods to carry away the fumes. Lead baths are especially adapted for heating small pieces that must be hardened in quantities. Gas is a satisfactory fuel for heating the crucible. It is important to use pure lead that is free from sulphur. Melting pots for molten lead baths, etc., should preferably be made from seamless drawn steel rather than from cast iron. Cast-steel melting pots, if properly made, are as durable as those made of seamless drawn steel.

Lead Burning. Lead burning may be defined as a form of autogenous welding, by means of which the parts to be united are joined by melting metal between them. This molten metal is obtained by heating the end of a strip of lead of the same composition as that of the lead plates to be united. The addition of metal at the joint is not actually necessary, but it serves to replace the material that is usually cut away before welding. The term "lead burning" is really a misnomer, because the lead is not burned so long as the welder does the work properly. The operation is essentially one of welding the lead with heat furnished by the combustion of hydrogen, and the technique of the operation is almost exactly the same as that of ordinary oxy-acetylene welding. Lead burning may be effectively performed with an oxy-acetylene welding torch, but great care must be taken, because the temperature of the oxy-acetylene flame is really too high for working on lead.

Leaded Bronze. This is an alloy containing 80 per cent of copper, 10 per cent of tin, and 10 per cent of lead, which melts at 945 degrees C. (1735 degrees F.).

Leaded Gun-Metal. This is an alloy consisting chiefly of copper and tin. The S. A. E. composition No. 63 follows: Copper, 86-89; tin, 9-11; lead, 1-2.5; zinc and other impurities, 0.50 max.; phosphorus, 0.25 max. This is a general utility bronze especially useful for bushings subjected to heavy loads.

Lead Foil. See Tin Foil and Lead Foil.

Lead Joint. This is a term generally used to signify the connection between pipes which is made by pouring molten lead into the annular space between a bell and spigot, and then making the lead tight by calking. The term is rarely used to mean the joint made by pressing the lead between adjacent pieces, as when a lead gasket is used between flanges.

Lead Monoxide. See Litharge.

Lead of Milling Machine. The lead of a helix (or "spiral" as it is commonly called) that would be generated in a milling machine during one revolution of the dividing-head, when the dividing-head is connected to the table feed-screw by gearing giving a speed ratio of 1 to 1, is known as the *lead of the machine.* Suppose the table feed-screw has 4 threads per inch, that 40 turns of the indexing crank or worm-shaft are required for one revolution of the dividing-head spindle, and that the worm-shaft and feed-screw are connected by gearing which causes them to rotate at the same speed; then, 40 turns of the feed-screw will be required for one complete revolution of the dividing-head spindle, and, as the feed-screw has 4 threads per inch, the total lengthwise movement of the table for one revolution of the dividing-head spindle will equal $40 \div 4 = 10$ inches; therefore, the lead of the spiral generated during one revolution of the dividing-head spindle will equal 10 inches, which is the lead of this particular milling machine.

Lead of Screw Threads. The lead of a screw thread is the distance the screw will travel forward in the nut if revolved one complete revolution. The lead of a screw thread should be distinguished from the *pitch* of the thread, which is the distance from center to center of two adjacent threads. In a single-threaded screw, the pitch and the lead are equal. If the screw is provided with a double thread, then the lead equals two times the pitch. In a triple thread, the lead equals three times the pitch. In designating a single-threaded screw thread, it is sufficient to give either the pitch or lead of the thread, but, in designating multiple-threaded screws, it is advisable to give both the lead

and the pitch in order to fully describe the thread. For example, a screw may be described as having "double thread, ½-inch lead, ¼-inch pitch." When so described, misunderstanding as to the meaning of lead and pitch is impossible, and mistakes in the shop are avoided.

Lead Pipe. Lead pipe is used to a very large extent for water systems for domestic purposes. It has been used for this purpose for centuries with entire satisfaction. Lead pipe for water systems, made from pure lead, is considered harmless as regards its influence on health, but mixtures with other metals, such as zinc, antimony, or tin, are dangerous and objectionable. The ultimate tensile strength of lead may be assumed to vary from 1600 to 2400 pounds per square inch. It is difficult to give the strength of lead with any certainty, because lead produced in Missouri, for example, is very much harder and stronger than so-called "desilverized" lead, and pipe made from the harder lead will stand a greater pressure.

Lead-Proof. A term applied to a method of testing the impression in a drop-forging die. See Drop-forging Dies, Lead-proof.

Lead-Screw. The lead-screw of an engine lathe is used for feeding the carriage when cutting threads. The carriage is engaged with this screw by means of two half-nuts that are free to slide vertically and are closed around the screw by operating a lever. Any screw which performs a similar function on other machine tools may properly be classed as a lead-screw.

Lead-Screw Steel. Lead-screw steel is a better grade than machine steel, and contains from 0.60 to 0.70 per cent carbon. Where machine parts are subjected to strain and shock such as shafts, studs, arbors, etc., which require a tough steel without hardening, lead-screw steel is commonly used.

Properties: Weight, 0.283 pound per cubic inch; 485 pounds per cubic foot. Specific gravity, 7.75. Strength: tension, 90,000 pounds per square inch; shear, 60,000 pounds per square inch. Melting point, 2600 degrees F.

Lead Wool. Lead wool is made of lead which has been shredded to about the size of heavy thread. After being shredded, the lead fibers are either collected in bundles and twisted together somewhat, or they are supplied in continuous strands coiled on reels. Lead wool is used principally for calking pipes, the lead being forced into the joint cold against a backing of hemp or tarred yarn. It is considered a good substitute for molten lead in calking joints for gas mains. The use of lead wool decreases the cost as compared with the use of molten lead. Very uniform

results are obtained by the use of lead wool, especially when calked with pneumatic hammers.

Leaf-Springs. See under Springs.

Leather, Effect of Humidity. The strength and elasticity of leather are greater in moist air than in dry, and for that reason it is important in making comparative tests of leather to be sure that they are made under the same humidity conditions. A given piece of leather tested in a dry atmosphere might appear to be weaker than a much poorer piece of leather tested in moist air. Experiments have shown that an increase of from 35 to 55 per cent in relative humidity increases the strength of leather 13 per cent and the stretch 16 per cent. When the humidity was raised from 35 to 75 per cent, the average increase in strength was 42 per cent and in stretch 53 per cent.

Leclanche Cell. This is a primary cell or battery having a zinc anode and a carbon cathode, with a solution of ammonium chloride (NH_4Cl) for the electrolyte, with a manganese dioxide depolarizer. The cell is used for open circuits, and gives a voltage of from 1.4 to 1.7 volts. The carbon cathode is placed in a porous cup which is filled with the manganese dioxide in the form of a coarse powder.

Ledloy. A steel in which lead is uniformly distributed throughout in such a fine state of dispersion that it cannot be seen under a microscope. In this form it has no effect on the physical properties of the steel, but makes it much more free-cutting. Ledloy 1120, for example, is said to machine from 30 to 60 per cent more easily than standard S A E 1120. Lead is added in amounts of 0.15 to 0.30 per cent. Important savings can be effected in the machining time of a large variety of parts such as gears, crankshafts, spindles, spline shafts, etc. The steel is available in all hot-rolled forms, and is also cold-finished by leading producers of cold-drawn steel.

Ledrite Brass Rod. Ledrite brass rod is a free-cutting material which is especially adapted for high-speed machining operations in connection with screw machine practice. It has long been known that the addition of a small amount of lead imparts free-cutting qualities to brass, as indicated by the fact that the chips have a tendency to break up into short pieces and thus prevent fouling the tools. This free-cutting action depends upon the fact that the lead is distributed as fine globules throughout the mass of the metal. The more thoroughly the molten metal in the melting furnace is stirred, the more finely will the lead be divided and the more evenly will it be distributed through the metal:

thus greater uniformity of cutting properties results. Ledrite brass rod is one of the products of the electric furnace.

Length Standards. See Standards of Length; also Light Wave as Length Standard.

Leveling Rod. One of the instruments used in surveying is the leveling rod. It consists of a wooden rod, usually 6½ feet high, graduated to hundredths of a foot, and provided with a sliding target. The rod is made in two parts, so arranged that its length can be extended to 12 feet. The target is provided with a vernier for accurate work, reading to thousandths of a foot. In using, the rod is held in a vertical position with its lower end resting upon the point, the elevation of which is desired, and the target moved up or down until its center coincides with the cross-wires of the telescope of the level. The reading of the elevation is made from the rod on a line corresponding with the center line of the target. There are several forms of rods in common use, some of which are read by the rodman, while others are read through the telescope of the level.

Levels. The accuracy of a spirit level depends entirely upon the curvature of the glass tube. This tube is ground on the inside to a barrel shape, except in cheap levels which simply have a glass tube bent to the approximate curve. The bent-tube type is not to be recommended except for work which does not require great accuracy. The tube is nearly filled with spirits of wine, ether, or some similar fluid, and is hermetically sealed at each end. The larger radius of curvature the glass has, the more sensitive will be the level. The air space in a ground glass is much longer than in a bent one, being ordinarily from one-fourth to one-third the length of the tube. Modern levels are graduated to tenths and twentieths of an inch, except when they are divided according to the metric system.

Level Glass Mounting: The leveling glass or "bubble" of a level is generally fixed in a brass tube with plaster-of-paris. This method has been found to be satisfactory for all levels having an accuracy of about five seconds angular measurement to each one-tenth inch graduation. For finer levels, it is better to fix one end only with plaster-of-paris and the other with cork, because, if the glass is fixed rigidly at both ends with plaster-of-paris, there will be a strain on the level due to temperature changes, and, as the expansion of glass and brass is different, a slight inaccuracy is liable to result. It is also advisable to have an extra glass tube surrounding the leveling tube for very accurate levels, in order to provide insulation from the heat of the hand. A level of one minute angular measurement to one-tenth inch

graduation is the most serviceable for general use. One having an accuracy of 30 seconds to one-tenth inch should be used on a floor free from vibration. Finer levels are used mostly on surveying and astronomical instruments.

Lever. A lever is the simplest element of a machine and may be defined as a bar used to exert a pressure or sustain a weight at one point in its length, by the application of a force at a second, and turning at a third on a fixed point called a *fulcrum*. The rotating effect of a force about a fulcrum is termed the *moment of the force* and equals the product obtained by multiplying the force by the perpendicular distance to the fulcrum. If the force is measured in pounds and the distance in feet, the moment is measured in pounds-feet; if the force is measured in pounds and the distance in inches, the moment is measured in pounds-inches. The most important principle to be observed with regard to moments is that the distance from the fulcrum to the force, generally called the "lever arm," must be measured

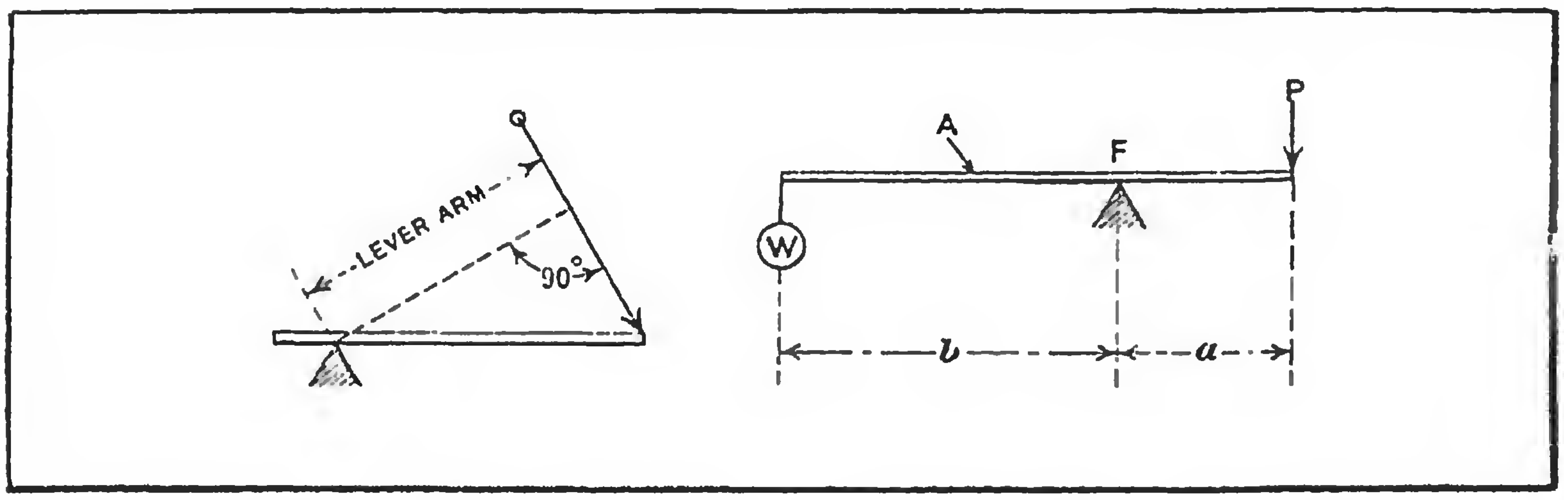


Fig. 1 Fig. 2

on a line at right angles to the direction of the force, as shown in Fig. 1.

The principle of moments is applied to a lever by the following rule: When two or more forces act upon a rigid body and tend to turn or rotate it about a fulcrum or axis, then, in order that equilibrium may exist, the sum of the moments of the forces which tend to turn the body in one direction must equal the sum of the moments of the forces which tend to turn it in the opposite direction about the same fulcrum. Thus, in Fig. 2, in order that the lever A shall be in equilibrium, it is necessary that the weight W times its distance from F shall equal the force P times its distance from F, or that the moment of the force P equals the moment of the weight W:

$$P \times a = W \times b.$$

If the weight sustained by the lever equals 20 pounds, the distance b equals 5 inches, and the force P equals 2 pounds, then the distance a must equal 50 inches in order that equilibrium may exist.

$$2 \times 50 = 20 \times 5.$$

See also Compound Levers; and Rolling Levers.

Lewis Formula: The Lewis formula is used extensively in determining the allowable power transmitting capacity of spur gears. It was introduced by Wilfred Lewis in 1892. In designing gears, the allowable tooth load may be based either upon tooth *strength* or tooth *wear*. If gearing is only used intermittently and for short periods, the allowable load would be based upon tooth strength (Lewis formula). However, tooth wear often is an important consideration; in that case, the power transmitting capacity both for strength and wear should be determined, and the smaller of the two values used. The Lewis formula, and also the formulas based upon tooth wear, will be found in engineering handbooks.

Leyden Jar. The Leyden jar or condenser is an electrical appliance devised for storing up small amounts of electrical energy in the early researches into the nature of electricity. It consists in its simplest form of a thin glass jar partly coated inside and outside with tin foil. When the two metal surfaces are connected for a short time with the terminals of some source of electromotive force, the electrical energy is stored up in the condenser and can be removed in the form of an electrical discharge.

Lifting Magnets. See Magnets, Lifting.

Lift of Water Pumps. The atmospheric pressure, as shown by a barometer, is changing constantly. The normal pressure at sea level is approximately 14.7 pounds per square inch. A column of water approximately 2.31 feet high exerts a pressure of one pound per square inch. Hence, with a normal atmospheric pressure of 14.7 pounds per square inch and a perfect vacuum in a pump chamber (assuming that a perfect vacuum were possible) the height of the lift would equal $14.7 \times 2.31 = 33.95$ feet, which is the maximum theoretical lift at sea level. The theoretical lift diminishes with an increase in altitude above sea level, because the higher the altitude, the less the atmospheric pressure. The theoretical lift for any altitude may be determined by multiplying the barometric reading in inches by 1.132. For liquids other than water, first find the theoretical lift for water, and then divide it by the specific gravity of the liquid.

As it is not possible to obtain a perfect vacuum in the cylinder of a pump, because of mechanical imperfections and also because of air contained in the water and vapor given off by the water, the actual maximum height to which water can be lifted is less than the theoretical height of 33.95 feet; furthermore, if it were possible to produce a perfect vacuum, a pump would not lift water to the maximum theoretical height, because some energy is required to overcome frictional resistance in the pipe, lift the suction valves, and maintain a supply of water in the pump cylinder equal to the rate of displacement or discharge. With good pump construction, the actual lift for water is only about 0.82 of the maximum theoretical height, and the average pump when in good working order will lift water about 0.75 of the theoretical lift, or from 25 to 26 feet at sea level. As a general rule, it is advisable to limit the height of lift to about 0.60 per cent of the maximum theoretical lift, or to about 20 feet at sea level.

Light Intensity Standard. See Candlepower; also Hefner Standard.

Lightning Arrester. A lightning arrester is a device designed to protect an electric system against excessive voltages caused by abnormal atmospheric conditions. A lightning arrester should not be expected to protect against direct lightning strokes, as it would be impossible for the arrester to dissipate the enormous amount of power accompanying such discharges. There are many different types of lightning arresters, the selection of the proper type depending not only upon the voltage of the system but also on its capacity.

Lightning Conductor. A lightning conductor is a metal rod or wire intended to provide means by which a lightning discharge may enter or leave the earth without passing through a non-conducting part of the structure to which it is attached.

According to the Safety Code for Protection Against Lightning prepared under the sponsorship of the National Bureau of Standards and the American Institute of Electrical Engineers, the following principles should be observed:

1. Structures should be examined and all points or parts most likely to be struck by lightning noted with the view of erecting air terminals thereon for the reception of the discharge.
2. Conductors should be installed with the view to offering the least possible obstruction to the passage of a discharge, avoiding sharp loops, bends, etc.
3. Ground connections should be distributed more or less symmetrically about the circumference of the structure, and at least two ground connections should be made at opposite extremities of the structure to avoid the passage of heavy ground

currents beneath its foundations. A rod driven 6 to 10 feet into the earth will ordinarily provide a satisfactory ground connection. A water-pipe connection is also satisfactory.

4. Metallic objects within a building which are liable to a dangerous rise of potential due to a lightning flash should, under some circumstances, be independently grounded.

5. The mechanical construction of the lightning conductor should be strong and, where possible, corrosion-resisting materials utilized.

6. The maximum permissible weight of copper conductor for all ordinary buildings is 187½ pounds per thousand feet.

Power plant chimneys should be provided with lightning conductors having copper points ¾ inch in diameter, 8 feet long, and with 1½-inch platinum tips. Two points should be used for chimneys less than 5 feet inside diameter and for larger chimneys one point should be added for every 2 feet increase in diameter.

Light Wave as Length Standard. In 1907 the wave length of cadmium light, as determined by Benoit, Fabry, and Perot, was adopted by the International Union for Cooperation in Solar Research (now the International Astronomical Union) as the international standard for all spectroscopic work. Since that time many other wave lengths have been determined, so that there are now available a very great number of secondary wave length standards accurately known in terms of cadmium waves.

The idea of using the wave length of light as a standard of length has been proposed by metrologists from time to time beginning even before Michelson's work. Michelson saw clearly the possibility of establishing the length of a meter bar at any future time by reference to light waves, if once the value of the wave length were determined, and pointed out the possibility of restoring the prototype meter if it should suffer loss or damage, and also the possibility of detecting any change in the standard meter bars. The possibility of such a control was also emphasized by Fabry, Perot, and Benoit who pointed out that the earlier proposals and laws for using a seconds pendulum or the earth's quadrant for these purposes do not fulfill modern requirements.

The relation between the meter and the wave length of cadmium light, as determined by Benoit, Fabry, and Perot, is as follows: 1 meter equals 1,553,164.13 wave lengths of red cadmium light. This wave length is based on standard conditions of temperature, pressure and humidity, and the number of waves per meter as given is probably correct to one part in 10,000,000, which means that the meter may be defined in terms of light waves with an accuracy of one part in 10,000,000.

Light-Wave Measuring Method. Light is a form of wave motion. Different colors of light have different wave lengths ranging from 0.0000169 inch (the average length of violet waves) to 0.0000268 inch for red waves. Daylight contains all the colors and has an average wave length of approximately 0.00002 inch. Monochromatic light is light in which one wave length or color predominates. The following explanations assume a monochromatic light having a wave length of 0.00002 inch.

An optical flat is a practically flat transparent test surface. Unlike a lens, it has no magnifying power. Interference bands, which occur between the contacting surface of an optical flat and a flat or nearly flat reflecting surface, appear as merging colored bands or fringes in daylight; and as alternate in monochromatic light.

When a series of straight interference bands occurs between two flat contacting surfaces, there is always a wedge of air between them, contact being at one side only. The bands take a direction at right angles to the slope or direction of the wedge. The number of bands per inch indicates the steepness of the wedge, which increases in thickness from the point or side of contact at the rate of one-half wave length (0.00001 inch) per dark band. The pronounced light spot indicates the point of contact. The dark interference bands are not light waves, but simply show the points or spaces where the light waves reflected from one surface interfere with the waves reflected from the other surface. The light spaces show the point of reinforcement. It is the dark interference bands that indicate the useful measuring unit of 0.00001 inch.

Straight parallel and evenly spaced bands indicate a flat surface, and curved and irregular bands indicate a curved or irregular surface. One of the earliest devices to be used in mechanics was the wedge. It is this elementary mechanical principle that is employed in comparing the length of two flat gage blocks, and also for measuring diameters of cylindrical plugs and balls. Two optical flats are used to form the wedge. The thickness of the wedge is fixed at one point by the thickness or length of a known standard gage block, and at another point by the diameter of the ball or cylindrical plug being measured. From the position, direction, and spacing of the interference bands, the slope of the wedge is found and, consequently, the exact amount that the ball or plug is larger or smaller than the standard is easily determined.

Light-Weight Metals. See Electron Metal; also Magnalium.

Lignite or Brown Coal. Lignite, also known as "brown coal," contains less than 50 per cent of carbon and over 50 per cent of volatile matter, and has a heating power per pound of combustible of from 11,000 to 13,500 B.T.U. Lignite may be divided into two

classes: (1) Sub-bituminous coal, also known as lignite, black lignite, brown coal, lignitic coal, etc.; this kind resembles bituminous coal, is black and shiny, but disintegrates more rapidly when exposed to the air, and its heating value is not as high as that of bituminous coal; (2) lignite, also known as brown lignite or brown coal, is distinctly brown in color and has a woody structure. It contains from 30 to 40 per cent of moisture, and has a lower heating value than any of the other coals. It is, in fact, intermediate between coal and peat, and is fragile, splitting into small pieces when exposed to the air.

Lime Set. In blast-furnace operation a lime set is caused by a slip allowing a large amount of limestone to drop into the molten mass of metal, so that the slag becomes too thick to flow out of the furnace.

Limit. In every interchangeable mechanism there are certain maximum and minimum sizes for each part, between which the parts will function properly in conjunction with each other and outside of which they will not. These sizes are the absolute limits of the parts. The established limits are the maximum and minimum dimensions specified on the drawings. The words *limit* and *tolerance* are often used interchangeably but tolerance represents the difference between the minimum and maximum limits. See Tolerance.

Limit Gages. With the modern system of interchangeable manufacture, machine parts are made to a definite size within certain limits which are varied according to the accuracy required, which, in turn, depends upon the nature of the work. In order to insure having all parts of a given size or class within the prescribed limit, so that they can readily be assembled without extra and unnecessary fitting, what are known as *limit gages* are used. One form of limit gage for external measurement is double-ended and has a "go" end and a "not go" end; that is, when the work is reduced to the correct size, one end of the gage will pass over it, but not the other end. Limit gages are very generally used for the final inspection of machine parts, as well as for testing sizes during the machining process. They are superior to the micrometer for many classes of inspection work, because the adjustment and reading necessary with a micrometer not only requires more time but often results in slight variations of measurement, especially when the readings are taken by different workmen.

Lincoln Type Milling Machine. See Milling Machines, Lincoln Type.

Line of Action in Gearing. The term "line of action" as applied to gearing means the line that would be described by the

point of contact of two gear teeth from the time they come into contact until they separate. Gear teeth having a form based on a system of curves such as the involute and cycloidal systems have a fixed line of action and the point of contact of any two gears of an interchangeable system, that mesh correctly, must follow this fixed line.

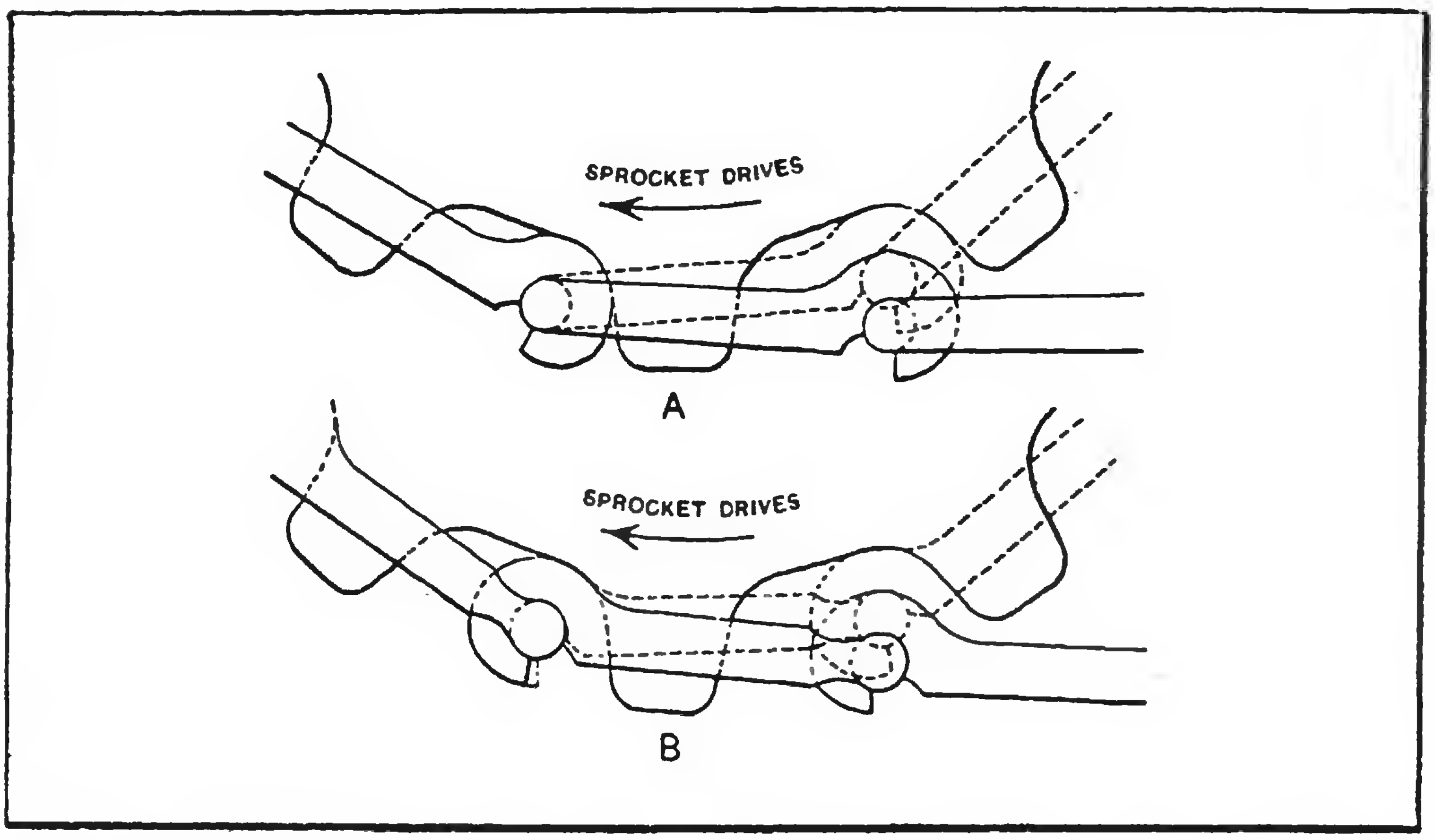
Line-Shafting. Long continuous lines of shafting for transmitting and distributing power in shops and factories are known as *line-shafting*. In general, shafting up to three inches in diameter is almost always made from cold-rolled steel. This shafting is true and straight and needs no turning, but if several keyways are cut in the shaft, it must, as a rule, be straightened afterwards, as the cutting of the keyways relieves the tension on the surface of the shaft due to the cold-rolling process. Sizes of shafting from three to five inches in diameter may either be cold-rolled or turned, although turning is more common and is always employed for sizes of shafting larger than five inches. In calculating line-shafts, the strength to resist torsion, as well as the stiffness to resist angular deflection and deflection between bearings, must be considered. Large diameter shafts of no considerable length need be calculated for strength only; long, slender shafts must also be calculated for stiffness.

Link. A link is a surveyor's length measure, equal to 7.92 inches.

Link-Belt. The chain known as a "detachable link-belt" or link-chain was invented by Wm. D. Ewart, in 1873. This type of chain was applied originally to harvesting machinery but is now used for many different classes of transmission service, and especially for all kinds of elevating and conveying machinery. The chain is made of refined malleable iron, and the links are connected directly by hook-shaped ends, each link having a hook at one end which engages the plain end of the adjacent hook. The sizes of detachable link-belting are designated by numbers. These chains are made in a number of different types or patterns suitable for different purposes. Some of these patterns are adapted for conveyor chains but are not suitable for power transmission, and vice versa.

Whenever possible, a link-belt should run with the back of the coupling hook to the sprocket wheel. The action is considered good when all of the bending takes place at the joint of the chain, as shown at *A*. (See illustration.) The dotted lines show the position of the link after bending, and the action is such that all of the wear is internal or on the inside of the hook. The action is considered bad when in bending the link rubs on the sprocket, thus wearing both the sprocket and the hook, as indicated at *B*.

Linotype Metal. Linotype metal, used for casting the slugs of type on linotype machines, is composed of an alloy of lead, tin, and antimony. The proportions vary somewhat, but, as a general average, the composition consists of 85 per cent of lead, 3 per cent of tin, and 12 per cent of antimony. Antimony is used in this metal because it has the quality of making the alloy expand upon cooling, thus filling the mold completely and making the type sharp and distinct. An alloy consisting of 82 per cent of lead, 5 per cent of tin, and 13 per cent of antimony is used to a great extent for newspaper work, and is said to work equally well for linotype, monotype, and stereotype.



(A) Link so Applied that all Wear is Internal or Inside of the Hook.
(B) With Link in this Position there is Wear on the Outside and Inside of the Hook and on the Sprocket

Liquid Air. See Liquid Oxygen.

Liquid Controller. This is an electric motor controller which may be either of the hand-operated non-automatic type or power operated. The hand-operated controller is used for small motors and consists simply of electrodes immersed in a solution of soda and water, the resistance being changed by elevating or lowering the plates in the solution, thus changing the immersed area of the plates. This controller is seldom used. The power-operated type is based upon the same principle of action, but is semi-automatic in its action and has been extensively used for large motors, 400 horsepower and above.

Liquid Glue. See Glues for Wood.

Liquid Measure. 1 U. S. gallon = 0.1337 cubic foot = 231 cubic inches = 4 quarts = 8 pints; 1 quart = 2 pints = 8 gills; 1 pint = 4 gills; 1 British Imperial gallon = 1.2009 U. S. gallons = 277.42 cubic inches; 1 cubic foot = 7.48 U. S. gallons.

Liquid Oxygen. Oxygen was first liquefied by the French scientist, Louis-Paul Cailletet. Liquid oxygen is air reduced to liquid form, from which, in the process of powerful compression, the nitrogen is distilled off. In the alternating process of compression and expansion through which it is produced, it reaches a temperature of 312.7 degrees Fahrenheit, below Zero. In its quiescent form liquid oxygen instantly freezes all substances immersed in it. Poured on ice, it vigorously boils, so much colder is it than the ice itself.

Liquid Oxygen Explosive. Liquid oxygen explosive, or L.O.X. as it has become known, is made by mixing very finely divided carbon, in the form of lampblack or carbon black, with the liquid oxygen which is highly concentrated oxygen. The association of the carbon and the oxygen is so intimate that when combustion is started due to a fuse or detonator, the carbon instantaneously burns and creates a large volume of high temperature carbon dioxide gas. At the moment of combustion, or explosion, the temperature of liquid oxygen jumps from 269.5 degrees below Zero to 5,603 degrees above, a variation of 5,872 degrees. The shattering force of this combustion is sufficient to rend huge strata of deeply imbedded rock. The practicability of liquid oxygen as an explosive has been put to test by the United States Bureau of Mines, in collaboration with scientists engaged in its development. It has been found particularly advantageous in blasting rock in quarries or in other open rock formations. One pound of liquid oxygen, together with one-fifth of a pound of carbon, with which it is packed in the cartridge, will do the work of one pound of 40 per cent dynamite. The safety of blasting with L.O.X. is one of its characteristics, recognized officially by the Bureau of Mines. Danger from accidental explosion is much reduced. Its cartridges cannot be set off except by a very severe shock such as the impact of a bullet.

Liquid Rheostat. Same as Liquid Controller.

Litharge. Litharge, or lead monoxide, is formed by heating lead intensely for several hours. It is yellowish red, very heavy, and grinds in 9 per cent of oil. A strong cement which is oil-proof, waterproof, and acid-proof, consists of a stiff paste of glycerin and litharge. These form a chemical combination which sets in a few minutes. If a little water is added, it sets more slowly, which is often an advantage. This cement is mixed when required for use. A handy cement for stopping leaks, etc., and

which can be used for cementing glass, brass, etc., is made by mixing equal parts of litharge, commercial glycerin and Portland cement. This cement will harden under water and will withstand hydrocarbon vapors.

Lithium. Lithium, an element, is the lightest of all metals. It has a specific gravity of 0.534, an atomic number of 3, an atomic weight of 6.940, and a melting point of 186 degrees C. The metal has a silvery-white appearance but tarnishes quickly when exposed to air. It is considered unstable and will burn with a bright flame in air when heated to a little above its melting point. Because of its instability, it is generally stored submerged in kerosene.

Lithopone. Lithopone is produced by mixing a solution of zinc sulphate with one of barium sulphide, and is used for the making of paints for the protection of iron and steel against corrosion. It is the whitest pigment known, and is widely used in high-grade enamel. It has a specific gravity of 4.25 and grinds in 13 per cent of oil.

Live Center. A live center is a center on which work is held in a machine tool and which revolves with the work. In a lathe, the center mounted in the revolving or headstock spindle is the live center.

Live Wire. The term "live wire" is commonly applied to an electrical conductor charged with electricity.

Lloyd & Lloyd Thread. The Lloyd & Lloyd screw thread is the same as the regular Whitworth screw thread in which the sides of the thread form an angle of 55 degrees with one another. The top and bottom of the thread are rounded.

Load-and-Fire Mechanism. When a reversal of motion of a machine member depends upon the action of a clutch which may be shifted from one gear to another revolving in an opposite direction, it is essential to operate the clutch rapidly and to secure a full engagement of the clutch teeth. One form of control may be defined as the swinging-latch type and another as the beveled-plunger type. The general principle of operation is the same in each case, and is as follows: When the work table, or whatever part is to be reversed, approaches the end of its stroke, a spring is compressed, and then a latch or trip allows this compressed spring to suddenly and rapidly throw the reversing clutch from one gear to the other. Reversing mechanisms of this general design are often called the "load-and-fire" type, because the spring is first loaded or compressed and then tripped to secure a rapid movement of the clutch and a reversal of motion at a predetermined point within close limits. Provision should also be made

against disengagement of the clutch as the result of vibrations incident to the operation of the machine.

Loaded Grinding Wheel. A grinding wheel is "loaded" when the pores or interstices between the cutting particles are partly or entirely clogged with the material being ground. Loading prevents the wheel from cutting and causes excessive heat to be generated. If a wheel becomes loaded, the bond may be too hard or the speed too slow. The remedy for loading is to increase the speed or use a softer wheel.

Load Factor. The load factor of a machine, plant, or system is the ratio of the average power to the maximum power during a certain period of time. The average power is taken over a certain period of time, such as a day, a month, or a year, and the maximum is taken as the average over a short interval of maximum load within that period. In each case, the interval of maximum load and the period over which the average is taken should be definitely specified, such as a "half-hour monthly" load factor. The proper interval and period are usually dependent upon local conditions and upon the purpose for which the load factor is to be used.

Loam Core. A loam core is a large core for castings made from loam on a cast-iron core-barrel so that the core is hollow. If made solid, it would be very heavy and difficult to handle. In making a loam core, the core-barrel is first wound with rope and a loam mixture is applied in a comparatively soft state and smoothed out over the surface, the barrel being turned during this process, so that the core is formed to a circular section at all points.

Local Hardening. Steel parts may be hardened locally, instead of throughout, in order to provide a hard wear-resisting surface for one section and at the same time secure greater strength or toughness of the part as a whole, by leaving the remainder soft. Local hardening may also be done primarily, to prevent excessive distortion which might result from complete hardening. The local hardening of tool steel requires some method of preventing the sudden cooling of the parts that are to remain soft, and local hardening of case-hardened steel requires some method of preventing carburization wherever the surfaces are to remain soft. A compound having the trade name "Localhard" provides a chill-resisting coating for tool steel for protecting the part that is to remain soft from the sudden cooling action of the quenching bath. This preparation liberates hydrogen gas (the greatest known non-conductor) when the hot steel is plunged into water so that the steel thus protected retains its heat long enough to prevent sudden cooling and consequently remains soft. This protective coating automatically separates from the steel which is left clean.

Local Carburizing: In carburizing parts preparatory to casehardening there are several ways of preventing portions of the work from being exposed to the carbon-carrying gases. A satisfactory method of local carburizing, when the volume of the work warrants it, is the copper-plating method. It is well known that it is impossible to harden copper by heat-treatment, because carbon is the chief hardening element in metals, and there is no affinity between copper and carbon. The copper is plated on the work by the electroplating process. A coating of copper sulphate is unsatisfactory, as there is no bond between the steel and the copper. In order to eliminate mechanical removal of the copper, japanning of the surface desired to be carburized is often resorted to before copper-plating. After baking the japan on, the work is plated, but the copper does not adhere to the japanned portion. The japan burns off in the carburizing process, and the steel formerly covered by the japan becomes carburized.

Localcase is a substitute for copper plating in local casehardening. The surface or surfaces that are to resist carburization and remain soft are covered with Localcase. This compound is also used to resist the oxidation of metals while heating.

Another method is to cover the sections that are to be kept free from an increase in carbon with fireclay mixed with water to the consistency of putty, then dried by moderately slow heat, and finally packed in the pots with a carburizer in the ordinary manner.

A metal protecting sleeve is practical where the form of the work warrants its use. This method consists of slipping a sleeve or collar over the part required to be free from an increase of carbon. The sleeve is either a push or loose fit, and if the latter, it can be wired in place.

Asbestos is often used in local carburizing by wrapping it around the section desired to be kept free from an increase in carbon and binding it in place with bundling wire.

A thin paste of water glass (sodium silicate) and kaolin (a fine grade of clay) may be painted on sections of the work that are to be kept free from an increase in carbon. Used sand-blast sand in a finely divided state is often mixed with this. This mixture is dried on the work by air, after which the work is packed in pots in the regular way. See also Tocco Hardening Process.

Lock-Joint, Converse. See Converse Lock-joint.

Lock-Nut. A lock-nut, also known as a check-nut, is a supplementary nut screwed down upon another in order to prevent it from becoming loose, due to the vibration of the machinery onto which the nut is attached. A *nut-lock* is a device for fastening a nut in place so that it will not become loose. A great variety

of means have been devised for locking a nut in place so as to prevent accidental loosening of the parts held together by the nut on its bolt.

Lock-Nut Pipe Thread. The lock-nut pipe thread is a straight thread of the largest diameter which can be cut on a pipe. Its form is identical with that of the American or Briggs standard taper pipe thread. In general, "Go" gages only are required. These consist of a straight-threaded plug representing the minimum female lock-nut thread, and a straight-threaded ring representing the maximum male lock-nut thread. This thread is used only to hold parts together, or to retain a collar on the pipe. It is never used where a tight threaded joint is required.

Locomotive Crane. This is a pillar crane mounted upon wheels and arranged to travel longitudinally upon rails. It is provided with a steam engine capable of propelling it along the rails and with steam power for hoisting and moving the load.

Locomotive Development. The first steam locomotive which ever ran on rails was built in 1804 by Richard Trevithick, an Englishman, and the first one to be used on a commercial basis was built by Matthew Murray, another Englishman. In 1811, Blenkinsop of Leeds, had several locomotives built by Murray in order to operate a railway extending from Middletown Colliers to Leeds, a distance of three and one-half miles. Trevithick's impracticable design had a single cylinder only, but Murray used two cylinders which were utilized in driving the same shaft on which cranks were set at right angles—an important arrangement common to all modern locomotives. A cog-wheel, or gear, meshing with a continuous rack laid along the road-bed was employed. These locomotives were used daily for years and were examined by George Stephenson when he began his work on locomotive development. Several years after the construction of Murray's locomotives Hedley and Stephenson demonstrated that the gear and rack method of propulsion was unnecessary, and that the frictional resistance of smooth drivers would supply adequate tractive power. Stephenson's name will always be associated with locomotive development owing to his accomplishments in perfecting the locomotive and in establishing it on a commercial basis. His first locomotive was tried on the Killingworth Railway in 1814. The first locomotive to be used in the United States was imported from England in 1829.

Lodestone. The most highly magnetic substances are iron and steel. Nickel and cobalt are also magnetic, but in a less degree. The name "magnet" has been derived from that of Magnesia, a town in Asia Minor, where an iron ore was found in early

days which had the power of attracting iron. This ore is known as *magnetite* and consists of about 72 per cent, by weight, of iron and 28 per cent of oxygen, the chemical formula being Fe_3O_4. The ore possessing this magnetic property is also known as *lodestone.* If a bar of hardened steel is rubbed with a piece of lodestone, it will acquire magnetic properties similar to those of the lodestone itself.

Log$_e$. This is an abbreviation designating natural, hyperbolic or Napierian logarithms.

Logarithmic Charts. Logarithms are a valuable aid to engineers and draftsmen in facilitating lengthy calculations both by hand and by the slide-rule which has logarithmic scales. They are of further use in the construction of nomographic or alignment charts which make possible the rapid completion of a number of computations based on the same formula. Thus, a problem containing a number of factors can be drawn into chart form so that anyone can obtain correct results even though the mathematical processes may not be fully understood.

In their simplest form, logarithmic alignment charts permit the rapid multiplication or division of two factors to get a third. Thus, in the equation $A \times B = C$, A, B and C are represented by vertical lines on which are laid out logarithmic scales with suitable values. By placing a straight-edge across the vertical line representing factor A and the vertical line representing factor B so that it coincides with the proper number indicated on the logarithmic scale of each, the answer or correct value of C may be read as a number at the point where the straight-edge crosses the logarithmic scale on vertical line C.

Probably the one thing that tends to discourage a more general use of these charts is the fact that they appear difficult to draw. Actually, the chart for simple multiplication or division just mentioned may be constructed quite easily. Thus, the scale representing factor A and the scale representing factor B may be any convenient length and distance apart. To lay out suitable logarithmic scales on each of the two vertical lines representing factors A and B, a piece of logarithmic cross-section paper is, in each case, placed at such an angle with one of the vertical lines, that the two extreme divisions desired just coincide with the horizontal extension of the ends of the line. The intermediate divisions can then be marked off by the intersection of parallel horizontal lines drawn from the intermediate divisions of the cross-section paper. The numbers or scale values can then be placed against each division.

Next comes the problem of placing the vertical line to represent the factor C at the proper horizontal distance from lines A and B. This can be accomplished by drawing two lines, each connecting

two numbers on the A and B scales, the products of which are equal, such as point 2 on line A and point 100 on line B and point 10 on line A and point 20 on line B. The point at which these two lines intersect marks one point through which the vertical line C must pass. This point will also be given the numerical value of the product of the two sets of numbers used on scales A and B which would be 200 in this case. The vertical line C is now drawn and several of the points on it can be numbered simply by placing a straight-edge across lines A and B indicating the intersection on line C and placing a number on this point which equals the product of the corresponding numbers on A and B. With these points established and numbered, the logarithmic scale can be laid out, again with the aid of a piece of logarithmic cross-section paper placed at a suitable angle with line C. The remaining numbers can now be placed against the intermediate divisions. The chart is then ready for use. When the ruler is laid across any two numbers on scales A and B, their product can be read directly on scale C. When the ruler is laid across any two values on the A and C scales, the quotient of C divided by A can be read directly on the B scale.

Logarithmic Paper. Logarithmic paper is a cross-section ruled paper used for plotting diagrams, in which the spacing between the lines is arranged according to the logarithmic scale, the object of this being to obtain greater simplicity in the plotting of equations containing exponents, in diagrammatical form. The cross-section paper on the market is ruled in the following ways: 1. Divided horizontally and vertically into centimeters and millimeters. 2. Divided horizontally and vertically into inches and eighths or tenths of an inch. 3. Divided horizontally into inches and tenths, and vertically, logarithmic, from 1 to 10. 4. Divided both ways, logarithmic, from 1 to 10. 5. Divided both ways, logarithmic, from 1 to 100.

In science and engineering, the law of variation in quantities is usually expressed as an equation. When this equation is of the first degree, it is graphically plotted on cross-section paper as a straight line. When the variable enters in any other power or root than the first, a curve results. On ordinary square-sectioned paper, plotting a curve is very laborious, as a great many points must be found in order to obtain the shape of the curve. In tracing a curve through the plotted points, it is difficult to obtain a draftsman's irregular curve which will "fit," and, as a result, the curve as drawn is only correct at the plotted points. When the equation has the form $x = ay^m$, in which the exponent m is of any power or any root, logarithmic paper has a distinct advantage over ordinary square-sectioned paper. As its name implies, it is divided logarithmically, that is, the distance of the

abscissas and the ordinates from the origin are proportional to the logarithms of the numbers instead of to the numbers themselves. Where a great many diagrams are to be made, logarithmic paper is a time-saver. It may be used for purposes of calculation in many ways which will suggest themselves to the engineer. Among the more common uses to which it may be put are the following: Powers and roots of any and all indices; bending moment, shearing stress, or deflection of beams in terms of span or load; moments of inertia and radii of gyration in terms of a linear dimension; circumferences and areas of circles in terms of their diameters; sizes of bars, struts, shafts, etc., in terms of a linear dimension; hydraulic equations, etc.

Logarithmic Scale. A logarithmic scale is constructed so that the distance is the same between all division numbers of the same multiple. Thus, the distance on such a scale between division numbers such, for example, as 3 and 9, 9 and 27, 30 and 90, and 100 and 300 is exactly the same. Upon looking at a piece of logarithmic cross-section paper, it will be observed that the pattern of lines seems to repeat itself. Thus, as one progresses from one end of the paper to the other, he finds at first that the lines are quite far apart but each succeeding line is closer to the preceding one until the end of a "cycle" is reached and the same pattern is repeated with lines at first far apart but getting closer to each succeeding line. The points at which each pattern begins are customarily given a value of some multiple of ten. Having established the value of one of these major divisions (as 0.001; 1; 100; 10,000, etc.) then each succeeding main division or start of a new "cycle" will have a value of ten times that of the one preceding. Thus, the major divisions of a logarithmic scale might read 0.001; 0.01; 0.1; 1, etc., or 1000; 10,000; 100,000; 1,000,000 with corresponding intermediate values between the major divisions.

Logarithms. The purpose of logarithms is to facilitate and shorten calculations involving multiplication, division, the extraction of roots, and the obtaining of powers of numbers. In the common or Briggs system of logarithms, the *base* of the logarithms is 10; that is, the logarithm is the *exponent* that would be affixed to 10 in order to give the number corresponding to the logarithm. For example log 20 = 1.30103, which is the same as to say that $10^{1.30103} = 20$. Log 100 = 2, and $10^2 = 100$. As $10^1 = 10$, the logarithm of 10 = 1. It is known from algebra that $10^0 = 1$; hence the logarithm of 1 = 0. While most of the tables of logarithms are given to five decimals, it should be understood that the logarithm of a number can be calculated with any degree of accuracy; hence, there are tables giving the logarithms with as many as seven decimal places, and some, used for very

accurate scientific investigations, giving as many as ten or more decimals. Tables of logarithms and information about their application will be found in MACHINERY'S Handbook.

Lohmannizing. The protection of iron and steel has generally been effected by means of zinc-coating processes. The process of "Lohmannizing," invented by H. J. Lohmann, differs in that it is not restricted to the application of zinc coatings, but may be used for coatings of zinc, lead, and tin in varying proportions to suit the requirements of each case.

Loom Bolt. This is a bolt having an oval head beneath which the bolt is square for a short distance. The other end of the bolt is threaded for a distance equal to about twice its diameter, for a square nut.

"Lost Wax" Casting. See Investment Casting.

Low Brass. So-called "low" brasses which are especially suitable for hot rolling, contain from 37 to 45 per cent of zinc, the remainder being copper. Other low brasses contain as little as 20 per cent of zinc.

Low-Carbon Steel. This term is applied to steel containing generally from 0.10 to 0.25 per cent of carbon, but it sometimes includes all steels up to about 0.60 per cent of carbon. Low-carbon steel is used for structural purposes and for machine building. It does not contain enough carbon to harden appreciably if heated and quenched, but may be case-hardened by first carburizing the surface.

Lowenherz Thread. The Lowenherz thread is intended for the fine screws of instruments and is based on the metric system. It has been adopted by the Bureau of Standards as there has been a lack of uniformity in the screws applied to American-made instruments. The Lowenherz thread has flats at the top and bottom the same as the U. S. standard form, but the angle is 53 degrees 8 minutes. The depth equals 0.75 $\times$ the pitch, and the width of the flats at the top and bottom is equal to 0.125 $\times$ the pitch. This screw thread is used extensively for the fine threads of measuring instruments, optical apparatus, etc., especially in Germany.

Lowmoor Iron. Lowmoor iron is the name used for the best grade of wrought iron made in England. Its chief characteristics are as follows: Wrought-iron bars, 1 square inch in cross-section and less, have a tensile strength of 50,000 pounds per square inch and an elongation in ten inches of 26 per cent. For bars having a cross-section up to 8 square inches, the tensile strength is about 48,000 pounds per square inch, with an elongation of from 22 to 24 per cent in ten inches. For bars larger than 8 square inches in cross-section, the tensile strength may be assumed as 46,000 pounds per square inch, with an elongation of 21 per cent in ten

inches. These tensile strengths relate to tests *with* the grain; *across* the grain, the strength of Lowmoor iron may be taken as 42,000 pounds per square inch, and the elongation in eight inches as 12 per cent.

Low-Voltage Trip. A low-voltage trip is an arrangement used in connection with a circuit-breaker for tripping when the voltage of the circuit falls off to a predetermined amount; in practice, this is usually about one-half of the full line-voltage. It may be used in connection with a time-delay mechanism so that the circuit is not opened for voltage fluctuations of extremely short duration; or an instantaneous closing device may be incorporated to automatically reclose the circuit three separate times in case the low voltage is only momentary. After the third reclosure, the breaker will remain open if the low voltage is still present.

Lozenge Chisel. Same as Diamond Chisel.

Lubricants. Proper lubrication is so very important that it is advisable to obtain information from a specialist experienced in the selection of lubricants for different classes of service. The method of applying the lubricant is also very important. In selecting an oil for a definite application, determine first just what the oil has to do to provide proper lubrication. The size of the bearings, pressure, speed of the shaft, and the clearance are essential factors. Bearings subject to high speeds and a low pressure require fairly light oil. Slow speeds and high pressures require sufficient body in the lubricant to prevent metal-to-metal contact in starting. At the same time, the lubricant should not be so viscous that undue loss of power will result from the internal friction of the lubricant itself; but too light an oil will not keep the metal surfaces apart and undue wear will result.

In order to facilitate starting machines subjected to cold weather, the oil should have a low pour-test. It is possible for bearings to wear as much during the first few minutes of a warming-up period, as in weeks under normal operating conditions. As the oil becomes warmer, the viscosity becomes lower and, in a measure, adjusts itself, assuming, of course, that it has been chosen to provide the correct body at normal operating temperatures. In this connection, attention may be called to the fact that a reduction in bearing temperatures may be obtained through the use of an oil that has the right viscosity at operating temperatures.

Most oils offered for industrial lubrication are straight refined petroleum products. However, in some instances, it is desirable to blend mineral oils with animal or vegetable oils. Cylinder oils, for instance, are often compounded with from 4 to 6 per cent of acidless tallow to make them adhere to metal surfaces. It is erroneous to assume that any grade of oil or grease that has

proved satisfactory on certain types of equipment will serve equally well on any other, especially where the operating conditions are different. In many plants perhaps a single grade of steam-cylinder oil, a medium-viscosity machine oil, and a medium- or light-consistency cup grease may suffice. Normally, however, in the modern industrial plant, the equipment involved is so designed as to include a considerable number of wearing elements of widely differing construction. Just as this construction differs, so may it be expected that the lubricating requirements will differ. In many cases, similar lubricants can be used; on the other hand, every case should receive individual attention in deciding upon the lubricants that will promote most efficient operation. In this way, production can be most surely maintained at minimum cost.

Viscosity and Load-carrying Capacity: Viscosity is to some extent indicative of load-carrying capacity. In fact, before the advent of "extreme pressure lubricants," it used to be regarded as the predominating characteristic of an oil for such service, on the assumption that the heavier-bodied products would better resist the squeezing-out effect of heavy journal or gear-tooth loads. Later, however, resistance to shear and film strength were proved to be more related to the chemical nature of the lubricant, a definite chemical reaction between the lubricant and the metallic surfaces under load being required. Research has further proved that the greater the smoothness or polish of the metallic surfaces to be lubricated, the more tenacious and resistant to pressure will be a film of straight mineral oil; hence, the trend in machine manufacture to use more care in the machining of journal bearings and gear-tooth surfaces.

Grease Lubricants: The term "grease" is applied to a mixture of mineral oil with fats that have been saponified with an alkali. To this mixture, fillers may or may not be added. Grease lubricant is available in three general classes known as hard grease, soft grease, and non-fluid oil. Suppliers usually classify greases as hard, medium-hard, medium, soft, and semi-fluid. The consistency may be indicated by numbers as, for example, No. 1, No. 2, and No. 3. In comparison with oil, grease occupies a minor yet important place in the field of lubrication. It provides a solid lubricant for use where a fluid is not practicable, or at least not economical, as in certain types of vertical and horizontal motors having ball or roller bearings; in cases where the motor operates at an angle; in instances where the moving parts are so worn that oil will run away and be wasted; and in other places where oil will not "stay put."

Lubricating Systems. Machine bearings are lubricated by various devices ranging from simple oil holes or cups to elaborate

systems. The selection of a method depends upon such factors as speed, bearing pressure, and the importance of safeguarding against lubrication failure.

Lubrication by Felt Pads: Felt pads for distribution of lubricant may either be used alone, or in combination with grooves in the bushing or on the shaft. The felt not only insures a supply of oil on every part of the journal that it touches, but it filters the oil as well, and prevents the passing of grit or particles of metal. The pads are fitted into slots cut in boxes or bushings, and either dip into a well, or are simply fed through holes by a cam, or from some type of lubricator.

Use of Wicking: When wicking is used to supply bearings the piece of wick leads from the oil reservoir to the bearing surface; and the oil feeds up due to capillary attraction. This is a very elastic principle, and possesses two main advantages. One is that the oil is filtered and, consequently, no dirt is transmitted by the wick; the other, that a feed can be procured from a well or gear-box not necessarily situated close to the bearing.

Ring Oiling: A system most extensively employed for spindles and shafts is the ring-oiling method, which insures a larger flow than is caused by the pad device. It is used in conjunction with a reservoir for each bearing, or with a reservoir or box common to several bearings. The ring (or an endless chain) is hung loosely on the spindle, and revolves at a slow rate, thus bringing up oil from a well below the bearing. Large rings have a smaller area in contact with the shaft than have smaller rings and they also have a tendency to assume a position oblique to the shaft and to swing laterally; consequently, the diameter of the ring should not be too large. See also Oil-ring Design.

Oil Circulated by Pumps: Pump systems embody many arrangements of a varied character for the thorough distribution of the lubricant. In some machines, the same supply is utilized to flood the gears and bearings, being pumped up from the well at the base and falling from a perforated pipe in cascades onto the gears, while suitably arranged pipes conduct it into the bearings.

Gravity Lubrication Systems: Gravity systems of lubrication usually consist of a small number of distributing centers or manifolds from which oil is taken by piping as directly as possible to the various surfaces to be lubricated, each bearing point having its own independent pipe and set of connections. The aim of the gravity system, as of all lubrication systems, is to provide a reliable means of supplying the bearing surfaces with the proper amount of lubricating oil. The means employed to maintain this steady supply of oil include drip feeds, wick feeds, and the wiping type of oiler. Most manifolds are adapted to use either or both

drip and wick feeds. A drip feed consists of a simple cup or manifold mounted in a convenient position for filling and connected by a pipe or duct to each bearing to be oiled. For a wick feed, the siphoning effect of strands of worsted yarn is employed. The worsted wicks give a regular and reliable supply of oil and at the same time act as filters and strainers.

Forced-feed Lubrication: If bearing pressures and speeds are high it may be desirable, if not necessary, to force the lubricant into the bearing under pressure. The pressures for horizontal bearings ordinarily range from 15 to 30 pounds per square inch but higher pressures are required for certain thrust and step bearings and in connection with some other force-feed systems of lubrication.

Flooded Lubrication: The difference between flooded lubrication and forced lubrication is that, in the former case, the oil is supplied to the bearing under a low pressure which insures that the journal is always flooded at the point where the oil is applied, but the lubricant is not forced between the surfaces rubbing against each other. In the forced-lubrication system, the oil is supplied at a pressure which is greater than the pressure between the rubbing surfaces at the point of application of the oil, and hence, the oil is forced in between the surfaces.

Splash Lubrication for Gears: There are two methods for supplying and distributing lubrication in gear drives—the splash and the pressure systems. The splash system depends on the action of the teeth in the gear as they pass through a reservoir of lubricant in the base of the housing. To avoid excessive churning and foaming, the gear should dip only a comparatively small amount into the reservoir. Just how deep depends on the tooth velocity, the pitch, the design of the gear, and the type of lubricant. Usually the teeth dip in a little more than their own depth. There should be a large amount of lubricant in the reservoir. This requires a large trough, which should be of almost rectangular section and at no point close to the rotating gear teeth. Special gages are available to show the depth of lubricant. Where the splash from the gear teeth is to lubricate the bearings, often the lubricant which is splashed on the inside of the cover is collected in troughs which are cast as a part of the housing or cover, from which it flows to the bearings through passages or ducts. The return to the reservoir is through draining canals. Suitable seals are provided to prevent leakage along the shafts. Sometimes baffle plates and drip fins are used to further direct the lubricant.

Pressure System for Gears: The positive circulating or pressure system supplies the lubricant under pump or gravity pressure, through feed pipes, directly to the point of tooth en-

gagement and to the individual bearings. It is used where the tooth velocities and bearing speeds are so high that the lubricant churns and heats excessively from the action of the gear teeth if they are allowed to dip into it. Also, at very high speeds the lubricants are thrown off from the gear teeth by centrifugal force and must be applied to the point of tooth engagement through specially designed spray nozzles. A pump is required, usually of the gear or rotary type, driven directly from the gear unit itself through gears or chains, or by a separate motor. It is customary as a safeguard to include "tell-tales" or relays in the electrical hook-up, to insure a warning or shutdown if the pressure in the feed pipes becomes too low.

Centralized Lubrication Systems: Various forms of centralized lubrication systems are used to simplify and render more efficient the task of lubricating machines. In general, a central reservoir provides the supply of oil, which is conveyed to each bearing either through individual lines of tubing or through a single line of tubing that has branches extending to each of the different bearings. Oil is pumped into the lines either manually by a single movement of a lever or handle, or automatically by mechanical drive from some revolving shaft or other part of the machine. In either case, all bearings in the central system are lubricated simultaneously.

Lubrication with Metals and Metal Compounds. The use of metal and metal-compound films in bearings where organic lubricants are undesirable has been found to result in considerable reduced friction in many instances. Barium, chromium, aluminum, magnesium, zinc and molybdenum disulphide have all proved effective in varying degrees when applied as thin films to bearing surfaces.

Molybdenum disulphide may be applied as a dry powder to clean metal surfaces by rubbing or tumbling but it may also be mixed with certain carriers such as oil, grease, resin, and silicone. It is effective as a lubricant at both low (— 40 degrees F.) and high (+ 600 degrees F.) temperatures. At temperatures above 600 degrees F. it must be protected from oxidation. Molybdenum disulphide is an especially effective lubricant under high pressures. The lubricating action of this material does not seem to depend on an adsorbed film of moisture which means that it is effective under conditions where moisture is absent, as in a vacuum. At ordinary temperatures it is a dielectric and is relatively wet chemically. It is well suited for the prevention of galling and seizing even of the softest metals. In addition its main uses are: as an aid in the assembly and disassembly of close fitting parts; as a lubricant in the hot and cold working and forming of metals; and as a dielectric lubricant.

Lumber. Lumber is the product of the saw and planing mill not further manufactured than by sawing, resawing, and passing lengthwise through a standard planing machine, cross-cutting to length and working. When not in excess of one-quarter inch thickness and intended for use as veneering it is classified as veneer. According to the Simplified Practice Recommendations promulgated by the National Bureau of Standards, lumber is classified by its principal use as: yard lumber, factory and shop lumber, and structural lumber.

Yard lumber is defined as lumber of all sizes and patterns which is intended for general building purposes. Its grading is based on intended use and is applied to each piece without reference to size and length when graded and without consideration to further manufacture. As classified by size it includes: *strips,* which are yard lumber less than 2 inches thick and less than 8 inches wide; *boards,* which are yard lumber less than 2 inches thick but 8 inches or more wide; *dimension,* which includes all yard lumber except strips, boards and timbers; and *timbers,* which are yard lumber of 5 or more inches in the least dimension.

Factory and shop lumber is defined as lumber intended to be cut up for use in further manufacture. It is graded on the basis of the percentage of the area which will produce a limited number of cuttings of a specified, or of a given minimum, size and quality.

Structural lumber is defined as lumber that is 2 or more inches thick and 4 or more inches wide, intended for use where working stresses are required. The grading of structural lumber is based on the strength of the piece and the use of the entire piece. As classified by size and use it includes *joists* and *planks*—lumber from 2 inches to but not including 5 inches thick, and 4 or more inches wide, of rectangular cross section and graded with respect to its strength in bending, when loaded either on the narrow face as joist or on the wide face as plank; *beams* and *stringers*—lumber of rectangular cross section 5 or more inches thick and 8 or more inches wide and graded with respect to its strength in bending when loaded on the narrow face; and *posts* and *timbers*—pieces of square or approximately square cross section 5 by 5 inches and larger and graded primarily for use as posts or columns carrying longitudinal load, but adapted to miscellaneous uses in which strength in bending is not especially important.

Lumber, Manufactured. According to the Simplified Practice Recommendations promulgated by the National Bureau of Standards, lumber may be classified according to the extent which it is manufactured as:

Rough lumber which is lumber that is undressed as it comes from the saw.

Surfaced lumber which is lumber that is dressed by running it through a planer and may be surfaced on one or more sizes and edges.

Worked lumber which is lumber that has been run through a matching machine, sticker or molder and includes: *matched lumber* which has been worked to provide a close tongue-and-groove joint at the edges or, in the case of end-matched lumber, at the ends also; *shiplapped lumber* which has been worked to provide a close rabbetted or lapped joint at the edges; and *patterned lumber* which has been shaped to a patterned or molded form.

Lumber Water Content. The origin of lumber has a noticeable effect on its water content. Lumber or veneer (thin lumber produced usually by rotary cutting or flat slicing, sometimes by sawing), when produced from the log, contains a large proportion of water, ranging from 25 to 75 per cent of the total weight. One square foot (board measure, one inch thick) of gum lumber, weighing approximately five pounds when sawed, will be reduced to about three pounds when its water content of approximately one quart has been evaporated. Oak grown on a hillside may contain only a pint (approximately 1 lb.) and swamp gum may have from 2 to 4 pints of water per square foot, board measure. This water content of wood exists in two forms—free moisture and cell moisture. The former is readily evaporable in ordinary air drying, but the latter requires extensive air drying (several years) or artificial treatment in kilns. It is possible to use artificial means to remove the free moisture, but a simple air exposure is usually more economical.

Lumen Bronze. Lumen bronze is a bearing metal which combines in a marked degree the wearing qualities of babbitt with the strength and rigidity of phosphor-bronze. It is an alloy of zinc, copper, and aluminum, which, strictly speaking, therefore, is not a bronze at all, but a brass composition. It is from 20 to 25 per cent lighter in weight than ordinary bronze, is non-magnetic, is easily worked by machine tools, and is softer than machine steel, so that it will not score or cut the journal of the shaft. The weight per cubic inch is about 0.25 pound; the specific gravity, 6.93; the tensile strength, 33,000 pounds per square inch.

Lumnite. An aluminum cement having the trade name of "lumnite," consists essentially of 40 per cent alumina, 40 per cent lime, 15 per cent iron oxide, and 5 per cent silica, magnesia, etc. This material reaches its full strength in 24 hours as compared with 28 days for Portland cement. It has been found that it is unaffected by sea water or by sulphate-bearing ground waters.

M

Maag Gearing. In the design of the Maag system of gearing, a 15-degree pressure angle is maintained for large gears, but for relatively small gears the angles and also the blank diameters or positions of the teeth relative to the pitch circles, are varied with the idea of obtaining the most satisfactory operation for gearing of a given ratio. This is a departure from standardization and the use of gears which are interchangeable at standard center distances. Those advocating this system, however, believe that what is lost in this respect is more than gained by so forming the teeth of a gear and pinion of given ratio as to obtain more rolling and less sliding action combined with stronger teeth without under-cutting, even when the gears are very small. When necessary or desirable to use gears having possibly not more than five or six teeth, a practical tooth form may be obtained by changing the pressure angle and the relation of the tooth to its pitch circle, to suit the conditions. It has long been the practice to obtain an improvement of tooth shape by the enlargement of small spur and bevel pinions but with the Maag system, the plan is to so modify the relations between addenda, dedenda, and pressure angle as to secure what is considered the best tooth form for each particular ratio.

Machinability of Metal. The term "machinability" indicates the degree of resistance encountered in cutting a metal. If a metal is machinable, this implies cutting it under practical conditions or by the application of practical shop equipment. A hard metal that is machinable with a carbide tool may not be machinable with a steel tool. Even though the steel tool will cut the metal, if it will not continue cutting a reasonable length of time before sharpening is necessary, then we have an example of machinability that is impractical. It is evident, then, that the hardness of steel does not always show whether it is machinable or not, because we must consider the kind of cutting tool to be used and also such factors as the cutting speed, the kind and quantity of cutting fluid, if any, and the rigidity of the tool support. The maximum hardness of a machinable steel or other material, because of these variable factors, extends over a wide range which has been increased greatly since the introduction of carbide tools. The maximum hardness of a machinable material under one set of conditions, for example, might not exceed 200 Brinell, and under other conditions, it might range from 400 to 500 Brinell or even higher.

Machinability and Hardness: In cutting steels, the allowable cutting speed for a given tool life between grindings is, as a general rule, inversely proportional to the hardness *of a given steel.* To illustrate, tests in turning an alloy steel with a high-speed steel tool showed a cutting speed of 70 feet per minute when the hardness of the steel was 180 Brinell; the cutting speed had to be reduced to about 35 feet per minute when the hardness was increased to 360 Brinell, the life between tool grindings for these tests being 20 minutes in each case. The machinability of other steels of the same hardness might vary. For example, the tests just referred to showed more or less variation in the cutting speeds for steels of the same hardness, but having different compositions or properties. Thus, while there is a constant relationship between the hardness of a steel and its tensile strength, there is not the same constant relationship between steel hardness and machinability as applied to different steels.

"Machine-Hour" Overhead Distribution. See Overhead Expense Distribution.

Machine Nut Taps. A machine nut tap (or machine tap, as it is also generally called) is used for nut tapping in tapping machines, the same as the tapper tag. The names of these two taps are often confused. From a manufacturing point of view, however, there is distinct difference between the two kinds of taps. The tapper tap is a very simple design, but for some classes of work the machine tap is more satisfactory. The machine tap is threaded and relieved in a different manner, and is adapted for use in tough material and for heavy duty.

Machine Screws. The term "machine screw" is generally understood to mean a screw which enters a tapped hole in a machine part and one having a head that is slotted to receive a screw driver. Screws of this class are designated by numbers instead of the actual sizes (the numbers increasing with the diameter), excepting American Standard sizes ¼-inch and larger. See table. The basic form of thread is the American Standard.

The American Standard is very generally used in the United States, although there is still considerable demand for certain sizes or pitches conforming to the older A.S.M.E. standard. This continued use of the A.S.M.E. standard applies particularly to the No. 4 size with 36 threads per inch. While the No. 4-36 machine screw may eventually be superseded largely or entirely by the American Standard, at the present time, this No. 4-36 combination is used either largely or exclusively in many shops and usually is found in hardware stores. Manufacturers of taps

Machine Screw Sizes and Standard Pitches

Screw Number or Size	Outside Diameter of Screw Thread, Inch	Threads per Inch: National or American Standard: Coarse Thread Series	Threads per Inch: National or American Standard: Fine Thread Series	Threads per Inch: A.S.M.E. Standard: Standard	Threads per Inch: A.S.M.E. Standard: Special	Threads per Inch: Other Pitches Used by Some Manufacturers
0	0.060	..	80	80	.....	.....
1	0.073	64	72	72	64	.....
2	0.086	56	64	64	56	48
3	0.099	48	56	56	48	.....
4	0.112	40	48	48	40–36	32
5	0.125	40	44	44	40–36	32
6	0.138	32	40	40	36–32	30
7	0.151	..	..	36	32–30	.....
8	0.164	32	36	36	32–30	.....
9	0.177	..	..	32	30–24	.....
10	0.190	24	32	30	32–24	.....
12	0.216	24	28	28	24	20
14	0.242	..	..	24	20	18
$\frac{1}{4}$	0.250	20	28	..	.....	.....
16	0.268	..	..	22	20	18–16
18	0.294	..	..	20	18	16
$\frac{5}{16}$	0.3125	18	24	..	.....	.....
20	0.320	..	..	20	18	16
22	0.346	..	..	18	16	.....
24	0.372	..	..	16	18	14
$\frac{3}{8}$	0.375	16	24	..	.....	.....
26	0.398	..	..	16	14	.....
28	0.424	..	..	14	16	.....
$\frac{7}{16}$	0.4375	14	20	..	.....	.....
30	0.450	..	..	14	16	.....
$\frac{1}{2}$	0.500	13	20	..	.....	.....

Machinery

and dies continue to supply No. 4-36 tools chiefly, in response to the demand of the trade. The A.S.M.E. No. 14-20 and No. 14-24 also continue in use more or less, but present indications are that this No. 14 size is gradually being replaced by the ¼-inch size of the American Standard.

There are two series of pitches for American Standard machine screws. These are designated as the Coarse-thread Series and the Fine-thread Series. Approximately 80% of the machine screw production has the Coarse-thread Series and the remaining 20% the Fine-thread Series.

The nominal length of a machine screw depends upon the form of the head. The length of a "round head" or "fillister-head"

machine screw is measured under or up to the head. With the "flat-head" and "oval-head" forms, the length includes the countersunk or conical portion.

Machine Screw Taps. The regular (standard) machine screw taps are similar to the regular (standard) hand taps except that they are made in so-called numbered or machine screw sizes.

Spiral Pointed Machine Screw Taps: A regular (standard) machine screw tap having a fewer number of flutes and wider lands and having the cutting face of the first few threads ground at an angle to force the chips ahead to prevent clogging in the flutes.

Stub Machine Screw Taps: A machine screw tap having three flutes for all sizes and with a thread considerably shorter than a regular (standard) machine screw tap. For use in tapping thin metal, and to overcome breakage.

Spiral Pointed Stub Machine Screw Taps: A stub machine screw tap having two flutes with the cutting face of the first few threads ground at an angle to force the chips ahead and prevent clogging of the flutes.

Machine Steel. Machine steel is a black stock of a better grade of steel than cold-rolled steel and requires machining. It contains from 0.25 to 0.45 per cent carbon. It is the most commonly used steel, and is adapted for all machine parts that are not subject to strain or shock. For short shafts, studs, arbors, etc., it will give long service and withstand considerable strain if casehardened.

Machine Tool. A machine tool is a power-driven machine that is used in building other machinery. However, there are many other power-driven machines used for this purpose which are not classed as machine tools. In order to obtain a more specific definition, machine tools have been defined as machines which, when taken as a group, will reproduce themselves. But this definition also is quite general and does not clearly indicate the proper classification for certain border-line machines. A more specific definition follows:

Definition Based Upon Common Usage: A machine tool is any power-driven non-portable machine designed primarily for shaping and sizing metal parts, by the progressive removal of chips or by abrasion, from raw materials in the form of castings, forgings, bars, tubes, plates, and stampings. The machines for producing such raw materials are not machine tools according to the general usage of the term in the machine tool and machine-building industries. For example, rolling mills forging machines, power presses, die-casting machines, molding

machines, brakes or other metal-bending machines, and power-driven hammers are not classed as machine tools. Metal-cutting machines, such as punching and shearing machines, are also excluded from the machine tool classification.

Definition for Census: The Department of Commerce, in connection with the Census of Manufactures, classifies the machine tool industry for census purposes as follows: This industry "includes establishments primarily engaged in the manufacture of power-driven complete metal-working machines not portable by hand, having one or more tool and work-holding devices, used for progressively removing the metal in the form of chips. It also includes honing machines, lapping machines, and grinders. Rolling mill machinery, presses, brakes, shears, punches, etc., and accessories for machine tools and other metal-working machines are classified in other industries."

Definition for Custom Duties: The United States Treasury Department, in the collection of custom duties, defines machine tools as any machines operated by other than hand power, which employ a tool for working on metal. This is a very broad definition and includes many machines which are not classified as machine tools by the builders and users of such machines.

Single-Purpose Machine Tools: Many modern developments in the machine tool field pertain to designs that are more or less special. These machines range from "manufacturing types," resembling simplified standard designs of unusual rigidity and power, to "single purpose" machines built specifically for one operation. The semi-single-purpose type of machine, while designed for a given part, is arranged to accommodate different sizes, the idea, in some instances, being to care for possible future changes in the design of a product.

Machine Tool History. The development of simple tools into more complex designs to replace manual labor is comparatively recent, and may generally be considered as having begun near the end of the eighteenth century. The history of civilization since that time has been so profoundly affected by the work of the engineer and the mechanic that the past and the present century may well be called the "age of machinery." The facilities for cutting metal in 1780 were little better than those of the middle ages. The mechanics or millwrights of that day worked almost wholly with the hammer, chisel, and file. Without doubt, the best mechanics during the eighteenth century were the French, and their work contained suggestions of a number of the modern machine tools; but their tendency was toward refined handicraft and ingenious novelties, and they showed little inclination toward commercial production on a large scale. The real development of the modern machine tool has taken place

almost wholly in England and in the United States. The general machine tools, such as the lathe, planer, shaper, drill press, and steam hammer, and the small tools, such as taps and dies, were developed in England from about 1800 to 1850. In America, partially overlapping this period, but in the main in the latter part of the nineteenth century, were developed the automatic lathe, the universal milling machine, drop-hammers, special machine tools of various kinds, and the interchangeable system of manufacture, the last involving the use of jigs, fixtures, and limit-gages.

Machine Tool Motors. The load demand upon a motor driving a machine tool of the rotary type, such as a lathe, boring mill, or drilling machine, is made up of machine friction plus the power required to remove the metal. The relative values of these two items vary. The load demand of a reciprocating tool such as a planer or shaper, involves the same items and, in addition, the power required to start, stop, and reverse the reciprocating parts. The load of a rotary machine may be quite constant, as in the case of a lathe making a continuous cut. If the cut is not continuous, the load may fluctuate considerably. The load of a reciprocating machine is inherently of a fluctuating nature, and the reversing peaks may be an important or determining factor.

The frictional load of a machine tool depends upon its design, and cannot be determined by formula. It may be best found by test. The power required to remove metal depends upon the character of the metal, rate of removal, average thickness of chip before distortion, and type and condition of tool. The following figures are widely used for lathes, shapers, boring mills, and planers:

Material	Horsepower Required to Remove 1 Cubic Inch per Minute
Brass	0.2 to 0.3
Cast iron	0.3 to 0.5
Wrought iron	0.6
Mild steel (0.30 to 0.40 carbon)	0.6
Hard steel (0.50 carbon)	1.00 to 1.25
Very hard tire steel	1.5

The power required for drilling is about double that given, due largely to friction between the drill and the side of the hole.

Heavy cuts requiring high torques are usually taken at relatively low speeds, while lighter cuts are taken at higher speeds. Thus the load tends toward a constant horsepower characteristic.

Motor Characteristics: Machine tools are sufficiently varied in their requirements so that several types of motors find application in individual cases. A considerable portion of the total field requires a constant-speed drive with no unusual features. Here

the direct-current, shunt motor or the alternating-current, squirrel-cage induction motor may be used with equal success. Either type will effect some gain over constant-speed belt drive from a line-shaft.

Many machine tools require adjustment of speeds over varied ranges, some as high as 30 to 1. Adjustable-speed direct-current motors are inherently best suited to such machine tools. Some machines, such as punches and shears, particularly when equipped with flywheels, require high starting and pull-out torque, together with drooping speed regulation. Here the compound-wound, direct-current motor or the high-slip induction motor is applicable.

Owing to the fact that alternating current is more commonly available, particularly in the smaller shops, the manufacturers of machine tools have adopted extensively the use of the gear-box for speed changes, thus adapting their tools for induction motor drive. For reasons of standardization, the same tools are then offered for use with constant-speed, direct-current motors, where the latter current is available. From the viewpoint of the machine tool builder, this standardization is desirable. In many cases, particularly for small machines, the practice is commendable. Where direct current is available, however, it will often benefit the user to employ adjustable-speed motors and eliminate the gear-box, or greatly reduce the number of change-gears required.

Adjustable-speed Direct-current Motors: The adjustable-speed direct-current motor is excellently suited to the requirements of many machine tools. Owing to varying diameters, materials, and cuts, it is necessary to operate over a wide range of speeds. A selection of speeds can be had by the use of cone pulleys, while a greater number is available by the use of a gear-box. The adjustable-speed motor provides a finely graduated selection of speeds over a range up to 4 to 1. If a wider range is desired, a simple set of change-gears will suffice to extend the range.

The great advantage to be derived from the use of the adjustable-speed, direct-current motor lies in the fact that maximum permissible cutting speeds may be maintained and the speed may be readily manipulated. When speed changes must be made in sizable increments, it is necessary to use a speed lower than but approaching the desired rate. The margin represents a direct loss of production. Increased production has the double aspect of lower unit cost and less time required, lowering the overhead and facilitating good deliveries and quick repairs.

Use of Induction Motors: It is not to be inferred that adjustable-speed, direct-current motors should be universally applied. When speed control features are unnecessary and a constant speed is satisfactory, the induction motor can be used to advantage.

Records indicate that induction motors are somewhat more free from troubles and require less repairs than direct-current motors. It is perfectly possible to have an equipment of direct-current motors and control, if properly selected and applied and properly maintained, that will require a few repairs. An induction motor, improperly applied or neglected, will stand up better than a direct-current motor under like conditions. It must also be considered that more is usually expected of the direct-current motor and control in the way of starting, stopping, reversing, and speed control, and the machine itself is thereby simplified.

In some cases, both alternating- and direct-current power supplies are available. In other cases, alternating current only or direct current only is available. Under the latter conditions, direct-current motors will be used exclusively. In a small shop where alternating current only is available, it is ordinarily best to use constant-speed, induction motors, foregoing the advantage of adjustable speed to avoid conversion. For larger shops, it may be advisable to install a converter or a motor-generator to supply direct current for all or a portion of the machines. The use of both alternating-current and direct-current motors in the same shop may or may not be advisable. When a number of large, constant-speed drives are required, alternating current should be used if available, even if a mixed installation results. If there are but a few constant-speed drives, direct-current motors may well be used for the sake of uniformity and to avoid two systems of current distribution. In some cases, direct-current motors have advantages in controllability even for constant-speed drives.

Mackenzie Alloy. A white metal composition containing either 68 per cent of lead, 16 per cent of antimony, and 16 per cent of bismuth, or 70 per cent of lead, 17 per cent of antimony, and 13 per cent of tin, is known as Mackenzie alloy. This alloy is a good stereotype metal.

Magaluma. This aluminum alloy is used for light alloy parts. Its composition is as follows: magnesium, 3.4; manganese, 0.15 per cent; and aluminum, the balance. This alloy may exhibit a tensile strength ranging from 29,000 to 50,000 pounds per square inch, a yield strength ranging from 10,000 to 42,500 pounds per square inch and an elongation ranging from 20 to 2 per cent depending upon whether it is in the soft or most hardened condition.

Magazine Feeding Mechanisms. Machines which operate on large numbers of duplicate parts which are separate or in the form of individual pieces are often equipped with a mechanism for automatically transferring the parts from a magazine or other retaining device, to the tools that perform the necessary operations. The magazine used in conjunction with mechanisms

of this kind is arranged for holding enough parts to supply the machine for a certain period, and it is equipped with a mechanical device for removing the parts separately from the magazine and placing them in the correct position wherever the operations are to be performed. The magazine may be in the form of a hopper, or the supply of parts to be operated upon by the machine may be held in some other way. The transfer of the parts from the hopper or main source of supply to the operating tools may be through a chute or passageway leading directly to the tools, or it may be necessary to convey the parts to the tools by an auxiliary transferring mechanism which acts in unison with the magazine feeding attachment. These automatic feeding mechanisms are usually designed especially for handling a certain product, although some types are capable of application to a limited range of work. See also Power Press Magazine Feeds.

Magnaflux Inspection. Magnaflux inspection exposes fatigue cracks, grinding checks, seams developed by the rolling mill, and so on. Flaws as deep as 2 inches below the surface that would defy detection even under a 20-power microscope are made readily apparent to the human eye. Surface cracks 0.0002 inch deep can be detected. Briefly, the Magnaflux principle as applied in the aircraft industry consists of magnetizing the parts to be inspected, so as to set up a polarity between any cracks or breaks either on the surface of the metal or below it for approximately 2 inches. The part is then immersed in an oil in which finely powdered black magnetic iron oxide is held in suspension or else it is sprayed or flooded with the oil. Particles of the iron oxide will adhere to the surface of the work wherever the polarity of a flaw attracts them, and these particles form a black line that is immediately observed by the inspector. Although the Magnaflux method of inspection has been universally adopted throughout the aircraft industry it is by no means confined to it.

Magnaglo Inspection. This method of inspection is similar to the Magnaflux method but differs in that fluorescent magnetic particles are used which can be seen more easily. This feature makes this method of inspection more sensitive than the Magnaflux method and enables the close inspection of parts with sharp corners and irregular surfaces.

Magnalium. Magnalium is a light-weight alloy composed of aluminum and a small percentage of magnesium. The composition varies, but the alloy generally contains from 1.6 to 2 per cent of magnesium. It also contains small percentages of copper, nickel, tin, and lead, the last-mentioned metal probably being an impurity. The specific gravity of this alloy varies from 2.5 to

2.57. The tensile strength of magnalium sand castings containing 2 per cent of magnesium is 17,900 pounds per square inch, while with 10 per cent of magnesium the tensile strength is increased to 21,400 pounds per square inch. Wire drawn from one quality of the alloy has a tensile strength of 41,000 pounds and 10 per cent reduction of area, while it will stand 53,000 pounds, if the raw material has been forged before drawing. Soft rolled sheets have a tensile strength of 42,000 pounds and 15 per cent reduction of area; hard rolled sheets, a tensile strength of about 52,000 pounds and 3 per cent reduction of area. Magnalium containing less than a certain percentage of aluminum cannot be rolled, but can readily be drawn. The tensile strength of a drawn bar when tested was 60,000 pounds, and that of a tube, 74,000 pounds per square inch. Magnalium can be cast in a manner similar to that employed for aluminum.

Magnesium Alloys. These alloys all contain over 85 per cent of magnesium. Pure magnesium is a relatively soft silver-white metal and does not possess the strength required for structural uses; but when alloyed with certain other metals, a wide range of properties may be obtained. Some alloys are characterized by their strength, others by their toughness, and still others by their thermal conductivity. The chief characteristic is extreme lightness, the average specific gravity being only 1.80. These magnesium alloys are designated by the trade name "Dowmetal." Dowmetal alloys are available for sand and permanent mold castings, die-castings, forgings, extruded shapes, plates, sheets and strips.

Compositions: The compositions vary more or less for different applications. For example, the aluminum content may range from 2.5 to 12 per cent; manganese, from 0.1 to 1.5 per cent; and some of the alloys have zinc varying from 0.5 to 3 per cent. The remainder of the composition in each case is magnesium. Some typical compositions for specific applications follow.

Sand Castings: The most commonly used alloys for sand casting are Dowmetals C and H. In addition to magnesium Dowmetal C contains about 9 per cent aluminum, 2 per cent zinc and 0.1 manganese, whereas Dowmetal H contains about 6 per cent aluminum, 3 per cent zinc and 0.2 manganese.

The normal unhindered shrinkage of magnesium alloys during casting is approximately 11/64 inch per foot. This shrinkage factor may be reduced to as low as ⅛ inch per foot on large castings or where shrinkage is restrained by cores. Thin walls should be kept relatively small in area. Thickness limitations, however, are approximately the same as for other non-ferrous metals.

Die-Castings: Dowmetal R is the most widely used alloy for die-castings. It combines good casting characteristics with desirable mechanical properties. This alloy contains about 9 per cent aluminum, 0.13 manganese, 0.6 zinc, and .3 silicon.

Forgings: The most widely used magnesium alloys for forgings are 0-1 where maximum strength is required, and J-1 when greater formability and weldability are desired. Dowmetal 0-1 contains about 8½ per cent aluminum, 0.2 manganese, and 0.6 zinc. Dowmetal J-1 contains about 6.5 aluminum, 0.2 manganese, and 1 zinc. Forgings are used for applications requiring higher properties than are obtainable in castings.

Extruded Shapes: Magnesium alloys may be extruded readily into a large variety of bars, rods, structural and special shapes. These extruded forms are held to close dimensional limits.

Mechanical Properties: The typical strength figures which follow are in pounds per square inch. Different casting alloys have ultimate tensile strengths varying from 22,000 to 40,000 with yield strengths from 12,000 to 23,000. Forgings vary in tensile strength from 35,000 to 50,000 and yield strengths from 23,000 to 34,000. Extrusions vary in tensile strength from 33,000 to 50,000 and in yield strength from 21,000 to 34,000.

The modulus of elasticity of magnesium alloys is 6,500,000 pounds per square inch. At temperatures as low as —100 degrees F., the mechanical properties of magnesium alloys differ only slightly from those at 70 degrees F. At elevated temperatures, there is a slight change in properties up to about 200 degrees F., but at higher temperatures there is a gradual reduction in tensile and yield strengths and an increase in elongation.

Magnesium Carbonate. Magnesium carbonate, commonly known as magnesia, is an impurity often found in boiler feed water. It is soluble in pure water. It is held in solution, if sufficient carbonic acid gas is present, the same as calcium carbonate, and is precipitated if this gas is driven off.

Magnesium Chloride. This is a compound which, when present in boiler feed water, has a corrosive effect and which is one of the causes of "pitting" in boilers. The corrosive effect of magnesium and calcium chlorides comes from the chlorine which is liberated by certain chemical changes. Magnesium chloride is very soluble in water, and evolves heat when in solution.

Magnesium Sulphate. Magnesium sulphate (sulphate of magnesia or Epsom salts) dissolves very slowly in cold water, but dissolves easily in warm water. When present with calcium

carbonate, a chemical reaction takes place which produces hydrate of magnesia and calcium sulphate, resulting in the formation of a very hard scale in boiler feed water.

Magnet. A magnet is a body which possesses the property of attracting pieces of iron and steel with a force in excess of the gravitational force and which, when freely suspended, takes up a definite position north and south. A magnetic substance is one which, when placed in the proximity of a magnet or a conductor carrying an electric current, will acquire the properties of a magnet. The most highly magnetic substances are iron and steel.

Magnetic Attraction. The law governing the attractive or repulsive force of magnetism is the same as that which applies to gravity. When the distance between two magnetic poles is doubled, the intensity of the magnetic field is diminished to one-fourth; if tripled, the intensity of the field is reduced to one-ninth, etc. In other words, the attractive or repulsive force varies inversely as the square of the distance between the poles, it also varies proportionately as the product of the strength of the poles.

Magnetic Chucks. Magnetic chucks are devices by means of which objects of iron or steel may be held in position during machining operations, the holding power being the magnetism created by electromagnets in the chuck; hence, jaws, clamps, or bolts are not required. These chucks are made in rectangular, circular, and special forms and they are used on different types of machine tools such as surface grinders and planers.

Magnetic Clutches. Magnetic clutches may be obtained having horsepower ratings varying from one to two horsepower up to several hundred horsepower. Such clutches are adapted particularly for high-speed drives, for heavy duty, and for use when there is difficulty in starting a heavy load with a motor. Magnetic clutches are also useful when machinery must be stopped quickly, a brake being used in such cases in combination with the clutch. One design of magnetic clutch has the field or driving member and the armature or driven member each carried by a flexible spring-steel plate so that when current passes through the field winding, the armature is attracted to it and friction surfaces come into engagement. The magnetizing winding of the field receives current through two collector rings and graphite brushes, and direct current is used. The clutch driving capacity depends upon the friction surfaces which are held together by the magnetic attraction.

Magnetic Degree. The 360th part of the angle subtended, at the axis of an electrical machine, by a pair of its field poles, is

designated as a "magnetic degree." One mechanical degree is thus equal to as many magnetic degrees as there are pairs of poles in the machine.

Magnetic Inspection. An improved method of inspecting machine parts for hidden flaws without destruction of the parts has been developed by the General Electric Co. A constant magnetic field is produced, so that it penetrates through the entire thickness of a small area of the part to be inspected. The part is slowly revolved, in order to change continuously the section within the field, until the whole part is magnetically explored. Imperfections, such as blow-holes, hidden flaws, or non-homogeneous areas in the interior betray themselves by producing disturbances in the magnetic field at the surface of the inspected part, which are recorded by the testing instrument.

Magnetic Materials. All substances may be classified in one of three groups according to their behavior in the presence of a magnetic field:

Ferromagnetic materials are those which are strongly attracted or magnetized by a magnet or magnetic field and include iron, steel, nickel, cobalt, and such alloys as Permalloy, Hypernik, and Alnico.

Paramagnetic materials exhibit virtually no properties of attraction, repulsion, or magnetization when placed near a magnet or in a magnetic field. Most materials fall into this class.

Diamagnetic materials are those which are slightly repelled when placed near a magnet. Bismuth exhibits the strongest property of magnetic repulsion. Antimony, copper and silver also belong in this class.

From a commercial standpoint, those materials which are ferromagnetic may be divided into two classes:

Non-retentive materials are those which have a high permeability, low hysteresis loss, and require a relatively low coercive force. They may, therefore, be easily magnetized and demagnetized. Included in this class are cast iron, ingot iron, and electrical silicon sheet steel.

Retentive materials are those which have a comparatively high hysteresis loss, low permeability, and require a large coercive force. They are hard to magnetize but retain their magnetization to a high degree, and, therefore, make good permanent magnets. Included in this class are 0.85 per cent carbon steel, 2.00 per cent chromium steel, 5.00 per cent tungsten steel, cobalt steel, and nickel-aluminum steel.

Other magnetic materials—not properly classified in either of these groups—are used for special conditions, such as sensi-

tivity to temperature changes, satisfactory operation at high frequencies, etc.

Magnetic-Mechanical Analysis. Research work done abroad and at the U. S. Bureau of Standards has shown that the magnetic properties of iron and steel afford a valuable index to the structural conditions existing in such materials, which is of particular importance for those materials the strength or cutting properties of which are the essential factors. Not only do the initial processes of manufacture affect the magnetic characteristics, but subsequent heat-treatment also. Therefore, the magnetic test offers means of examining materials, tools, etc., during and after manufacture, without injuring or marring them, with a view to predetermining their mechanical performance. It also presents a method of investigating the "exceptional tool" or product, looking toward its routine duplication.

The method of "magnetic-mechanical analysis" is based upon the fundamental fact that "there is one, and only one, set of mechanical characteristics corresponding to a given set of magnetic characteristics, and conversely there is one, and only one, set of magnetic characteristics corresponding to a given set of mechanical characteristics." Consequently, the magnetic properties of iron and steel give valuable information concerning structural conditions existing in the material. Apparatus for investigation of mechanical properties by determination of their correlated magnetic characteristics is known as a "permeameter." This instrument may be used for testing milling cutters, reamers, twist drills, files, etc., and also for testing such products as wire, wire rope, drill rod, etc. An advantage of the method is that the entire piece is tested instead of a sample, and the test is made without in any way damaging the product, so that this method is equally applicable for use on raw materials and finished work.

Magnetism. Fundamentally, magnetism is explained by the electronic theory in terms of the behavior of the electron, which is considered to be the basic magnetic particle. Because the electron is an electric charge in motion, it constitutes, in effect, a minute electric current which, like all electric currents, produces a magnetic field. Where an atom is composed of several moving electrons whose magnetic fields do not completely neutralize each other, the atom itself may be considered to act as a magnet. In some cases, groups of such atoms are aligned in stable combinations with their magnetic fields in parallel with each other and when so aligned they tend to act together as a magnet.

For the purpose of simple explanation, all magnetic substances may be considered to be made up of these minute magnets which are either atoms or groups of atoms with magnetic fields. Now

in a bar of iron, for example, if these minute magnets are arranged so that their magnetic fields are pointing in every direction, they will neutralize each other and the bar as a whole will not be a magnet. If, however, these minute magnets are arranged so that their magnetic fields are lined up more in one direction than in another, the bar will be found to have magnetic poles and, in fact, has become a magnet. If these minute magnets are all lined up in the same direction, the bar becomes fully magnetized or *saturated.* The application of heat tends, by thermal agitation. to disarrange the position of these minute magnets and thus to remove the magnet property of the bar. A mechanical shock has the same tendency.

Any source of magnetism, such as a permanent magnet or an electromagnet, produces a magnetic field. This field may be considered to be made up of lines of magnetic flux, which form closed loops, passing out of the North pole of the magnet and around through the surrounding medium and back into the magnet at the South pole. In a simple magnetic circuit the relationships are mathematically similar to that of a simple electrical current. The magnetomotive force may be compared to electromotive force, the magnetic flux to electric current, and the reluctance of the magnetic circuit to the resistance of the electrical circuit. Then (using the proper magnetic units) the magnetic flux is equal to the magnetomotive force divided by the reluctance just as (using the proper electrical units) the electric current is equal to the electromotive force divided by the resistance. The physical analogy is not exact, however, for unchanging flux is thought of as a static condition in contrast to current, which is thought of as electricity in motion.

The kind of material in a magnetic circuit influences the amount of flux which passes through it per unit area. Thus, when an iron bar is placed in a magnetic field, it becomes magnetized—that is the minute magnets making up the bar are lined up in the direction of the field so that their individual magnetic fields enhance or increase the strength of the magnetic field passing through the bar. Materials which tend to greatly increase the density of magnetic fields passing through them as compared with the density in air are said to be ferromagnetic. Iron, cobalt, nickel and some of their alloys are materials of this kind. Such materials are used extensively in transformers, motors, generators and other electrical equipment where strong magnetic fields are required.

A magnetic needle, or compass needle, is a magnetized piece of iron or steel, which being free to turn, always tends to point north and south, owing to the earth's own magnetic field. See also Diamagnetism.

Magnetite. Magnetite is the purest form of iron ore found in nature, and contains the largest percentage of iron obtainable in any ore. It is also known as "magnetic oxide of iron," or "black oxide of iron." Magnetite is strongly attracted by a magnet; hence, its name. Magnetite sometimes possesses magnetic polarity, thus forming a natural magnet. The mineral is, in that case, known as "lodestone."

Iron is present in magnetite ores as a magnetic oxide, Fe_3O_4, which, when pure, contains 72.4 per cent of iron. Many of the commercial magnetite ores contain, as impurities, sulphur, phosphorus, and titanium, and sometimes the ore is mixed with an excess of rock, making the actual percentage of iron for a given weight comparatively small. Magnetite ore, when pure, is almost black, but the commercial ore varies in color from black to blue black, steel gray, or slightly green, having a hardness of from 5 to 6.5 on the Mohs hardness scale. See Iron in Iron Ore; also Hematite.

Magneto. A magneto or magneto-generator may be defined as a small and compact form of electric-current generator in which field excitation is produced by permanent magnets rather than by field coils. It is used for generating the small currents required for ignition purposes in internal combustion engines, for bell signals in telephone systems, etc. Where a high voltage is required for ignition purposes, primary and secondary windings are used on the armature which may be fixed, while the magnets rotate, or vice versa.

Magnets, Lifting. Lifting magnets are used in connection with power-operated cranes and hoists, for lifting magnetic material, especially where such material must be handled in bulk. They are especially useful in and around foundries, steel mills, etc., for lifting such materials as pig iron, metal plates, billets, scrap iron, steel castings, rails, "skull crackers," and, in fact, practically anything except non-magnetic metals, such as brass and copper. The magnet is energized by a direct-current and it greatly facilitates handling material of the classes mentioned, because the parts to be lifted are gripped or released by the magnet instantly and quite a number of pieces can be lifted at one time, especially in the case of small billets, plates, etc. *Pig magnets* are designed to handle material of irregular shape that is piled indiscriminately. *Plate magnets* are especially adapted for lifting straight shapes from orderly piles. *Bi-polar magnets* are designed for handling both of the classes of materials mentioned in the foregoing. There are also magnets of special form which are designed particularly for handling a certain class of material. All lifting magnets require direct current. Where

direct current is not available, it may be obtained by installing a motor-generator or engine-generator set.

Magnet Steel. Alloy steels are used for making permanent magnets. The composition of the steel depends to a large extent upon the class of service for which the magnets are to be used. Some magnets, for instance, are made from 0.50 to 0.60 per cent carbon steel, containing a fairly high percentage of manganese. When a stronger magnet is required, a 0.50 to 0.60 per cent carbon steel, with from 3 to 7 per cent of tungsten, is used. Steel containing 5½ per cent of tungsten makes excellent permanent magnets. Chromium steels are also used for magnets.

Magnolia Metal. A bearing metal composed of lead, tin, and antimony in somewhat varying proportions, but generally consisting of from 78 to 80 per cent of lead, from 15 to 16 per cent of antimony, and from 4.75 to 6 per cent of tin, is known as *magnolia metal.* In some samples, 0.25 per cent of bismuth and a trace of copper is present.

Major Diameter. The largest diameter of the thread on a screw or nut is the "major diameter." This term has been used to replace the term "outside diameter" as applied to the thread of a screw and also the term "full diameter" as applied to the thread of a nut. See also Minor Diameter.

Malleability. Malleability is a qualitative term describing the relative ease with which a metal can be deformed permanently under compression without rupture.

Malleable Castings. Malleable-iron castings are produced by subjecting ordinary white iron castings to a special heat-treatment, in order to make the castings tougher and to some extent malleable. Hard, brittle, white iron castings that have been cast in the usual manner are first cleaned to remove any sand which may adhere to them, and then are packed in cast-iron or malleable-iron boxes or pots, with powdered hematite ore or iron scale. It is customary to arrange these pots three high in an annealing furnace or oven. In sets of three high the cold oven is filled to capacity, the doors are closed and sealed with fire-clay, and the fire is started. The purpose of the scale is to keep the fire from direct contact with the castings. The temperature is raised to between 1400 and 1700 degrees F. and is maintained there for forty-eight hours or longer; then the fire is allowed to die out and the oven cools slowly. As it ordinarily takes two days to obtain the required temperature, the whole process may require eight days from the time the fires are started until the castings are removed. It is essential that the oven be cooled very slowly from its high temperature, as this is a determining factor in the quality of the product.

Physical Properties: Malleable iron possesses physical properties closely resembling those of wrought iron, and as it is primarily a cast metal, odd shapes, housings, etc., may be made which possess, to a marked degree, the properties of forged metal. Malleable iron is much stronger than cast iron, but weaker than steel castings, and can be bent and worked to some extent. Malleable iron can be hardened, and when so treated is especially adapted to the hardware class of castings. Malleable castings have a tensile strength commonly varying from 35,000 to 55,000 pounds per square inch with from 3 to 8 per cent elongation in two inches. Some castings have shown a tensile strength of from 60,000 to 63,000 pounds per square inch, and even stronger castings have been produced. Castings made of malleable iron may be subjected to repeated shocks for long periods without crystallization; they will withstand considerable distortion without breaking, and malleable iron has greater rust-resisting properties than any of the other ferrous metals. Therefore, malleable castings are extensively used on railway equipment, agricultural implements, and machinery and various other classes of work subjected to corrosion and shocks. Malleable iron is less susceptible to fatigue failure than steel castings.

Malleable Iron Brittleness: Numerous tests on samples of commercial malleable iron, mostly impact tests on specimens heat-treated at relatively low temperatures, show that the embrittlement of malleable iron sometimes noted in hot-dip galvanizing is due chiefly to the incidental heat-treatment. Quenching malleable iron from temperatures between 400 and 500 degrees C. (750 and 930 degrees F.) makes it brittle to a greater or lesser degree, depending on the iron. The rate of heating and the time the metal is held at this temperature exert but little influence. Aging after treatment has no apparent effect. On the other hand, substituting slower rates of cooling for the quenching treatment produces a metal of higher impact resistance. Heating to 650 degrees C. (1200 degrees F.) for a few minutes, followed by quenching (in water at room temperature), eliminates the embrittlement, even if the metal is subsequently galvanized.

Malleable Copper. Malleable copper, also known as virgin copper and native copper, is a metallic copper found in nature practically pure, having all the properties of refined metal. It is mined extensively in the Lake Superior district in the United States and in Bolivia.

Malleable Pig Iron. This is an American trade name for the pig iron suitable for converting into malleable castings through the process of melting, treating when molten, casting in a brittle state, and then making malleable without remelting.

Malleablizing. Malleablizing is a kind of annealing operation with slow cooling, resulting in the combined carbon in white cast iron being transformed to temper carbon; in some cases the carbon is entirely removed from the cast iron. Temper carbon is free carbon in the form of rounded nodules made up of an aggregate of minute crystals.

Mallory 3. Copper alloy possessing high strength. Elastic limit of rods, 50,000 pounds per square inch; ultimate strength, 70,000 pounds per square inch. Elastic limit of castings, 25,000 pounds per square inch; ultimate strength, 50,000 pounds per square inch. Castings have a high impact strength, retained at high temperatures. At about 775 degrees F., impact strength does not fall below 50 foot-pounds. Forgings and drawn rods have an electrical conductivity of 80 to 85 per cent that of copper, and sand castings 75 to 85 per cent that of forged copper. Brinell hardness of bars and rods, 150 or greater; of sand castings, 116 to 125. Used extensively for spot-welding tips, flash-welding dies, and seam-welding wheels, and for any other applications where a high-strength metal of high electrical conductivity is required. Obtainable in rods, bars, dies, drop-forgings, regular forgings, and sand castings; and in cold-drawn, swaged, cold-headed, or extruded parts.

Maltha. Maltha is a material obtained from Californian petroleum as a residue when the more volatile ingredients have been distilled off. It is used as a protective covering for sheet-steel riveted pipe. The maltha is thinned with mineral oils, heated, and the pipe dipped in it, the coating being allowed to dry in the air.

Manchester Pitch. The term "Manchester pitch" formerly was used to designate a pitch system for gearing, and it was originated by John George Bodmer in his plant at Manchester, England. Originally the pitch was obtained by dividing the pitch diameter by the number of teeth, thus obtaining a value similar to the module or metric pitch. The present diametral pitch obtained by dividing the number of teeth by the pitch diameter, is equivalent to the reciprocal of the old Manchester pitch system. See Diametral Pitch.

Mandrel. See Arbor and Mandrel.

Manganese. Manganese is one of the most important of the minor metals. The ores are obtained from many parts of the world, including the United States, Brazil, France, Germany, and India. Manganese is used extensively in the iron industries in the manufacture of iron-manganese alloys, such as spiegeleisen, ferromanganese, silver spiegel, and silicomanganese. Spiegeleisen and ferromanganese are used largely in the manufacture of steel, as reducing agents and recarburizers. A consider-

able quantity of high-grade manganese ore is also used as a depolarizer in the manufacture of dry-cell electric batteries. Manganese steels have many important qualities not found in other steels. Manganese-bronze is produced by alloying manganese with copper, while so-called "silver-bronze" is obtained by alloying manganese with aluminum, zinc, and copper. Oxides of manganese are used in glass manufacture, and as dryers of varnishes and paints. Manganese is also used as a coloring material for staining glass, tiles, and bricks, as well as in calico printing and dyeing. The specific gravity of manganese is 7.42, making the weight per cubic inch, 0.268 pound. The specific heat at 32 degrees F. is 0.122; the melting point of manganese is 1225 degrees C. (2237 degrees F.). Its electrical conductivity is 15.75, that of silver being taken as 100. Manganese is a metal having a close resemblance to iron in many respects.

Manganese-Bronze. There are a number of different manganese-bronzes which give satisfactory results. They generally contain from 56 to 60 per cent of copper, from 37 to 42 per cent of zinc, with small percentages of iron, tin, and manganese. The manganese content may not be more than 0.3 per cent, and sometimes less; nevertheless, it has a considerable influence upon the character of the alloy. Tests made indicate that the ultimate tensile strength of castings made from manganese-bronze of the composition mentioned is about 60,000 pounds per square inch, with an elastic limit of 30,000 pounds per square inch. Rolled manganese-bronze has a tensile strength up to 100,000 pounds per square inch, with an elastic limit of about 80,000 pounds per square inch. The elongation in rolled samples varies from 12 to 15 per cent, and in sand castings, from 8 to 10 per cent. The compressive strength of cast manganese-bronze varies from 125,000 to 135,000 pounds per square inch. Wrought manganese-bronze differs chiefly from the casting grade in being free from aluminum. The addition of aluminum enables the alloy to be cast satisfactorily in sand molds. In order to secure ductility as well as high tensile strength, extreme purity of the materials used is absolutely essential. Manganese-bronze is stronger and tougher than phosphor-bronze, and has a high corrosion resistance. It is adapted for use in parts such as screw propellers, large gears, bearings, brake-shoes, etc. This material is preferable to aluminum-bronze, as it is more easily handled in the foundry and produces better castings.

Manganese-Bronze Castings—S.A.E. Standard No. 43: This alloy is intended for castings requiring strength and toughness. It is used for such automotive parts as gear-shifter forks; counters, spiders; brackets and similar fittings; parts for starting motors; landing-gear and tail-skid castings for airplanes.

Composition of No. 43: Copper, 55 to 60; zinc, 38 to 42; tin, max., 1.50; manganese, max., 3.50; aluminum, max., 1.50; iron, max., 2; lead, max., 0.40 per cent.

Physical Properties: Tensile strength, 65,000 pounds per square inch; elongation in 2 inches (or proportionate gage length), 25 per cent.

Manganese Silver-Bronze. A so-called "manganese silver-bronze" alloy, which can be rolled into sheets and rods and drawn into wire, is composed of 18 per cent of manganese, 1.2 per cent of aluminum, 13 per cent of zinc, 67.3 per cent of copper, and 0.5 per cent of silicon. This alloy has a tensile strength of about 57,000 pounds per square inch with 20 per cent elongation. It can be drawn into wires as small as 0.008 inch in diameter. This alloy is useful as a resistance wire in electrical devices, because its conductivity for the electrical current is only 1/40 of that of pure copper; in fact, it has a much lower conductivity than that of German silver.

Manganese Steel. Manganese steel was first successfully produced by the Hadfields in England, about thirty years ago, and was known as "Hadfield steel." It was first made in the United States by the Taylor Iron & Steel Co., of High Bridge, N. J. Manganese steel is used for castings subjected to heavy strains, shocks, and excessive wear, such as the wearing parts of steam shovels, ore and rock crushers, mining machinery, etc. It is also used to a considerable extent for safes. When rolled and forged, it is used for rails, frogs, and crossings. The usual compositions for such applications lie between the following limits: carbon, 1.0 to 1.3 per cent; silicon, 0.3 to 0.8 per cent; manganese, 11.0 to 14.0 per cent; phosphorus, 0.05 to 0.08 per cent. Manganese steel is a hard self-hardening steel. It cannot be softened by heating followed by slow cooling, and, for a metal, is a poor conductor of electricity. Manganese steel has a high coefficient of expansion, small patterns being made with a shrinkage of 5/16 inch to the foot, which sometimes is not quite enough. A shrinkage of 5/16 inch to the foot gives a mean coefficient of expansion of about 0.000024 per degree C.

Perhaps the most remarkable property of manganese steel is its almost total lack of magnetic permeability and susceptibility. This metal, containing 85 per cent of iron in a metallic form, is so slightly attracted by a magnet that the pull cannot be felt by the hand, whereas magnetic oxide of iron, containing about 70 per cent of iron in a non-metallic form, is strongly attracted. The average commercial steel has a tensile strength of from 82,000 to 90,000 pounds per square inch, an elastic limit of from 45,000 to 60,000 pounds, and an elongation of about 30 per cent. Other approximate values are, compression, 163,000 pounds per square

inch; shear, 80,000 pounds per square inch; melting point, 2450 degrees F.; weight, 0.284 pound per cubic inch (490 pounds per cubic foot), specific gravity, 7.88.

S.A.E. Manganese Steels: The S.A.E. manganese alloy steels for certain applications in the automotive industry may be used interchangeably with other medium alloy steels of similar carbon content. There are four standard compositions with a carbon range of from 0.18-0.23 up to 0.38-0.43. The manganese range in all cases is 1.60 to 1.90 per cent. The manganese alloy steels having carbon ranges from 0.33 to 0.43 are primarily oil-hardening steels, and great care should be exercised in water quenching.

Manganin. Manganin is an alloy containing manganese, copper, and nickel, which is used for electrical purposes; it possesses the peculiar property of not altering its electrical resistance with a change in temperature. This alloy, therefore, is used for wires in the construction of resistance boxes, electrical instruments, and standards. The composition which has proved most suitable for ordinary purposes consists of 85 per cent of copper, 12 per cent of manganese, and 3 per cent of nickel.

Manhes Process. The Manhes process is a method of refining copper, which is similar to the Bessemer process for making steel. In the "bessemerizing of matte" by the *Manhes* or *converter* process, a blast is forced through the molten matte. In about 25 minutes this blast oxidizes all but a small quantity of iron and some sulphur, and has raised the product to white metal. The slag is poured and the blast again turned on for 30 or 40 minutes, when the sulphur is rapidly oxidized and the charge is reduced to metal containing 99 per cent of copper. Little or no slag results from the second blow; that from the first blow contains from one to two per cent of copper and is put into the reverberatory or blast furnace.

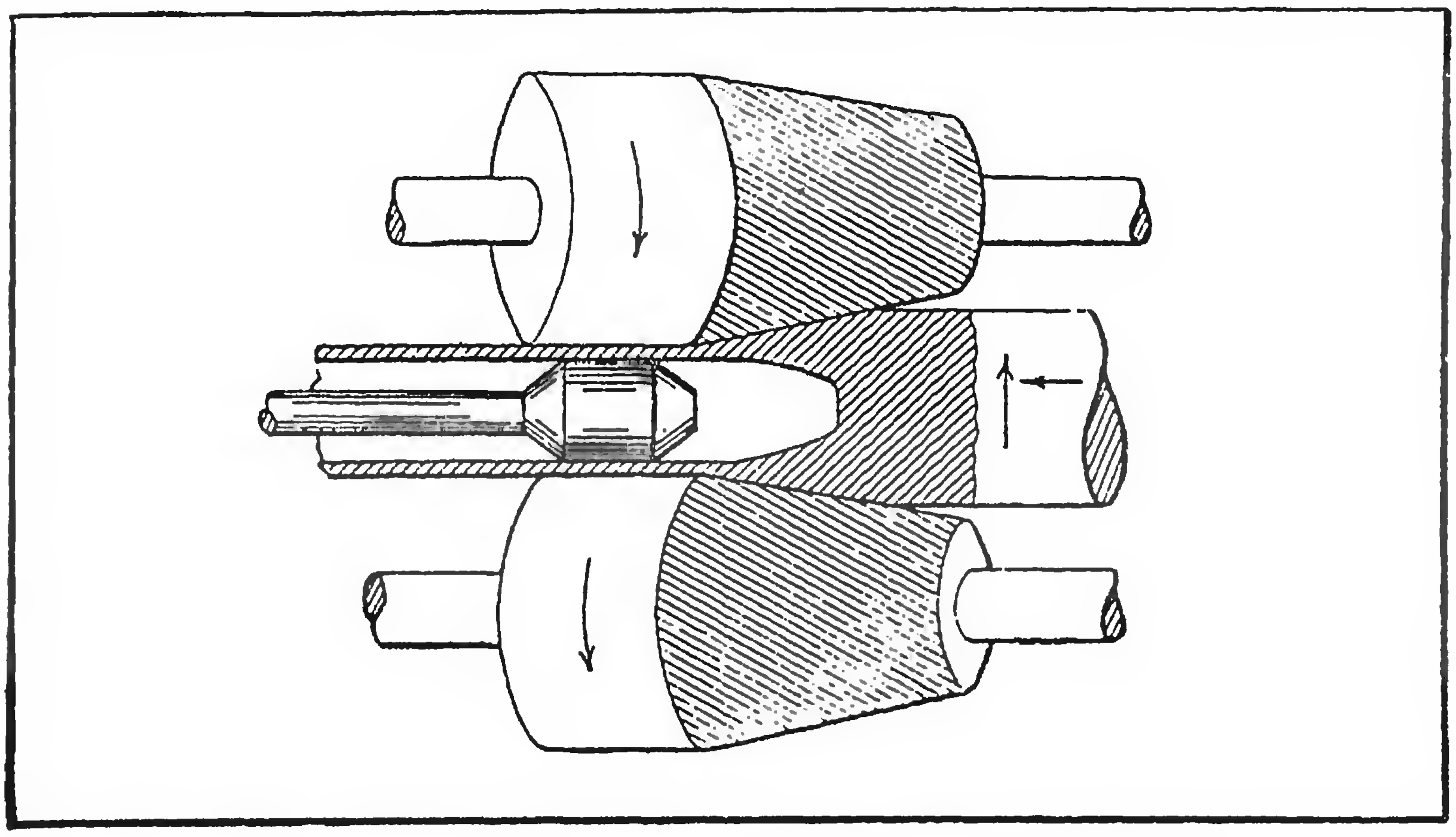
Manhole Dimensions. In a steam boiler, a manhole is an opening large enough to permit a man to enter the boiler for inspection or repairs. Elliptical manhole openings must not be less than 11 by 15 or 10 by 16 inches in size. Circular manhole openings must not be less than 15 inches in diameter.

"Man-Hour" Overhead Distribution. See Overhead Expense Distribution.

Manifold. (1) A fitting with numerous branches used to convey fluids between a large pipe and several smaller pipes. (2) A header for a coil.

Manila Rope Strength. Manila rope is made from fiber or hemp obtained from a plant that is a native of the Philippines. Its strength varies considerably, not only with the quality of the

fiber and the method by which the rope has been made, but also with the weather conditions under which it is used and the size and mounting of the sheaves over which it is run. Deterioration and wear is generally due to defective sheaves, excessive load, and exposure to outdoor atmospheric conditions. Manila rope in fairly good condition, ½ inch in diameter, should safely support 250 pounds; ¾ inch in diameter, 750 pounds; 1 inch in diameter, 1500 pounds; 1¼ inches in diameter, 2000 pounds; 1½ inches in diameter, 2500 pounds; 1¾ inches in diameter, 4000 pounds; 2 inches in diameter, 5000 pounds; 2¼ inches in diameter, 7000 pounds; and 2½ inches in diameter, 9000 pounds. When the load is supported by two or four parts of the rope, it is advisable not to multiply the load by two or four directly, but to make the load on several parts of rope slightly less than the theoretical safe load would be, figured from the safe load on a single rope, espe-



Mannesmann Process of Making Seamless Tubes

cially for large ropes. For example, when the safe load for a 2-inch rope is 5000 pounds, the safe load on two parts of rope may be 9000 pounds, and the safe load on four parts, 16,000 pounds.

Mannesmann Process. The piercing process used in the production of seamless tubes, commonly called the "Mannesmann process," is based upon the fact that the cross-rolling of a heated round bar of steel produces a rupturing of the material along its center line, and a tendency to form a hole along its longitudinal axis. The diagram illustrates the principle of the Mannesmann

piercing process. A round solid billet is passed between two rolls the axes of which are at an angle, as the illustration indicates. These rolls impart to the billet a high rotative speed and a slow advancing movement, forcing the billet over a pointed mandrel and thus increasing its length and changing it from the solid to the tubular form. The forward motion of the billet is caused by the inclination of the axes of the conical rolls relative to each other. A satisfactory explanation for the remarkable results obtained by this method is difficult to give. It seems that the material, instead of flowing in a longitudinal direction, as in ordinary rolling, has a tendency to flow outward toward the circumference, owing to the rotary motion, and a distinct displacement of the fiber takes place. This method of piercing billets can be applied in a number of ways.

Mannheim Gold. Mannheim gold is the name of an alloy containing, according to one authority, 89.44 per cent of copper and 9.14 per cent of zinc, the remainder being impurities; another authority gives the composition as 75 per cent of copper and 25 per cent of zinc, or 80 per cent of copper and 20 per cent of zinc.

Manograph. The manograph is the name of an instrument used for indicating engines of very high speed. It consists principally of a small mirror moved or tilted upward and downward by a diaphragm actuated by the pressure variations in the cylinder. The mirror is also rocked from side to side by a mechanism geared to the engine, in order to reproduce the reciprocating motion of the engine piston on a smaller scale. The principle of action of the device is based upon the fact that a beam of light is reflected by the mirror on a ground-glass screen, and this beam, by the movement of the mirror, traverses a path corresponding to that of the pencil point of an ordinary indicator. The diagram is traced by the beam of light on the ground-glass screen, and varies with the varying conditions in the cylinder. A photographic dry plate in a plate-holder may be substituted for the ground-glass screen, and the diagram may thus be photographed. The exposure varies from one-half to three seconds. The instrument is especially used on gas engines, where the speed is too high for the ordinary type of indicator.

Manometer. The manometer is an instrument for measuring the pressures exerted by gases or vapors; hence, the manometer is simply a pressure gage, although the term "pressure gage" is generally restricted to that type of manometer which is used in connection with steam boilers, air tanks, etc. The principle of the simplest form of manometer is based upon that law of hydrostatics according to which a liquid contained in a U-tube will

show the surfaces at the same height in both vertical legs, if the pressures on the surfaces of the liquid in both are equal; but, if the pressure in one leg is greater than that in the other, the surfaces will be at different heights, the difference being proportional to the difference in pressure, and inversely proportional to the specific gravity of the liquid.

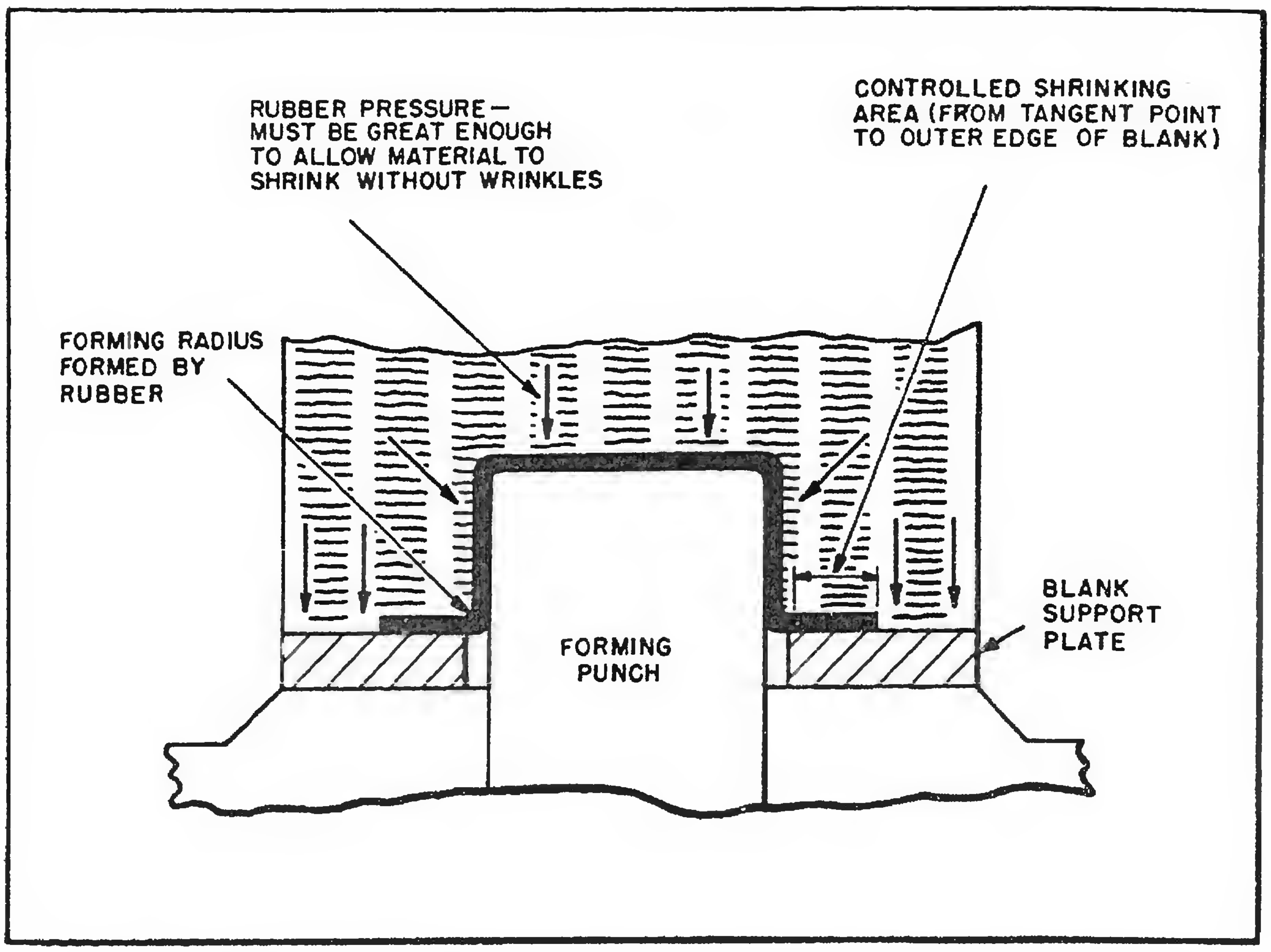
"Man-Rate" Overhead Distribution. See Overhead Expense Distribution.

Marble. Any limestone which is sufficiently compact to admit of being polished is known as "marble." Pure marble is white, but the presence of iron oxides or other impurities changes the color. Marble is of importance in electrical engineering, because of its insulating qualities, and is the material principally used for switchboard work, in which case it should contain no metallic veins, as these reduce its insulating qualities. The dielectric strength of marble is estimated at 6500 volts per millimeter (0.0394 inch). There is some difficulty in drilling or otherwise shaping marble. In drilling marble, the operation is greatly facilitated by grinding or filing a narrow slot in the point of the drill. This slot should be about ⅛ to ¼ deep, according to the size of the drill, and should form an angle of a little less than 90 degrees with the cutting edges. Marble is a difficult material to turn. When turning is necessary, it should be cut with a tool such as is used for brass, but at a speed suitable for cast iron. It must be handled very carefully in order to prevent flaws in the surface.

Marforming. This sheet-metal forming process involves the use of a rubber forming cushion combined with hydraulic equipment by means of which a close control can be maintained over the pressures employed in the forming cycle, thus preventing wrinkling of the work and keeping springback to a minimum.

In addition to drawing operations, the process can be utilized to form and trim flanged parts, as well as to shear in the same operation. The shearing action can be parallel to the forming stroke, perpendicular, or at any angle. Shearing is accomplished without additional dies or auxiliary devices.

The accompanying figure illustrates the principle of construction of the Marform tool. Here it can be seen that rubber is employed as the female portion of the tool. This has several advantages, one being that the rubber provides a cushioning effect, thereby preventing the rapid application of stress at any point on the metal and avoiding excess localized strains. The rubber also exerts a lateral pressure during the forming operation, as the direct result of the applied forming pressure. The lateral pressure has the effect of holding the formed metal



Essential Features of Marform Unit for Forming Sheet Metal Parts

tightly against the male portion of the tool, thus preventing concentration of stress at the punch radius and insuring a uniform distribution over the complete surface of the piece to be formed.

See also Guerin Process of Metal Forming.

Marine Glue. Marine glue, proof against the action of salt water, consists of 1 part of crude rubber, 2 parts of shellac, and 3 parts of pitch. The rubber is first dissolved in carbon disulphide or turpentine, and is then mixed with the heated combination of the two other ingredients.

Mariotte's Law. See Boyle's or Mariotte's Law.

Marking Machines. Marking machines are used for imprinting trade marks, firm names, etc., on either flat or round surfaces of metal parts or products such as cutlery, files, fire-arms, drills, taps, reamers, etc. There are various designs of marking machines, some of which are operated by hand and others by power. One general type is provided with either a round steel stamp for flat work, or a flat stamp for round work, and means of traversing either the die or work while both are held in contact with sufficient pressure to transfer the lettering or design from the steel stamp to the parts being marked. The necessary traversing move-

ment on small machines may be obtained by a crank or a hand lever, and on the larger machines by power derived either from a belt or motor drive. One type of power-marking machine is operated by placing a blank in position and starting the machine by foot treadle control; a cam then releases a weighted arm thereby raising the work-table and bringing the work into contact with the die which traverses across the work. When the stroke is completed the table drops, the work is released, the die returns to the first position, and the machine stops. During the return stroke, the imprinted blank can be removed and a new one inserted. Another marking machine especially intended for such parts as bushings, tool handle ferrules, light sockets, spark plug parts, etc., has a horizontal revolving dial which carries the work across the face of the marking die. If thin tubular pieces require internal support they are placed on mandrels. Parts can be marked very rapidly with a machine of this type.

Martensite. Martensite is one of the molecular states of steel, into which the metal changes when heated to the hardening temperature and quenched; martensite consists mostly of iron with 2 per cent or less of carbon; it forms the chief constituent of hardened steel. It is hard, brittle, and non-magnetic. When its composition corresponds with that of pearlite, and it contains 0.9 per cent of carbon, it is known as *hardenite*. See also Steel, Constituents or Structure.

Mass and Weight. The mass of a given body is a constant value by means of which the *quantity* of matter the body contains may be compared with that of another body. Mass is a ratio obtained by dividing the weight of the body by the acceleration due to gravity. According to the law of gravitation the attractive force by which one body tends to draw another body towards it, is directly proportional to its mass and inversely proportional to the square of the distance between the centers of the bodies. This attractive force is greatest at the earth's surface; above the surface it decreases as the *square* of the distance, and below the surface it decreases as the distance to the center decreases. With these fundamental laws in mind the meaning of weight and the distinction between it and mass will be more apparent.

If the weight of a body is determined by scales of the beam or lever-balance type, a measure of the quantity of matter is obtained because the body balances a standard weight unit and both body and weight unit are equally affected by gravity changes which would result either from a change of altitude or latitude; hence, weight determined in this way is constant regardless of locality. When a scale of the spring type is used, weight becomes a measure of the force of gravity and variations will occur, as-

suming that changes of altitude or latitude are sufficient to cause observable changes in the scale reading; hence the weight reading obtained with a spring type of scale might not be a true indication of the amount of matter, because with such a scale the force of gravity acts upon the body being weighed but does not appreciably affect the spring resistance. If the weight obtained with the spring type of scale is divided by the acceleration due to gravity for a given locality, the ratio obtained, which represents mass, will remain constant. To illustrate this point by using an extreme example, if the force of gravity is 32.16 (value commonly used in engineering) and the weight is 100 pounds, then mass equals $100 \div 32.16 = 3.11$. On the surface of the sun, where the force of gravity is twenty-eight times greater than on the earth, the same body would weigh 2800 pounds, but its mass would equal $\frac{28 \times 100}{28 \times 32.16} = 3.11$. In this instance, there would be an extreme variation in the apparent weight in pounds (assuming that the spring type of scale were used) but the ratio representing mass is the same in each case. The quantity of matter represented by a body weighing 100 pounds on the earth, would not be altered in any way by a change of locality; hence, it is evident that the value representing mass is an indication of the quantity of matter that a body contains and this is also true of the weight as determined by a scale of the beam-balancing type. Mass is used in many calculations, such as those involving the motion of bodies, when "weight" means the attraction due to the force of gravity, which is the common meaning in theoretical mechanics. Sometimes mass is expressed in pounds, but since it does not mean an equivalent number of standard weight units, but is a ratio between weight and acceleration due to gravity, the use of pounds in connection with mass is confusing, if not misleading.

Master Gages. Master gages are used only for verifying inspection gages, or for checking the product in case a disagreement arises between the manufacturer and the purchaser. Under the heading "master gages" are included various gages known as "checks," "masters," and "reference gages." Master gages should, if possible, be of the same design and construction as the inspection gages, but should have practically no allowance for wear. In some cases, checks or masters are made which are complements or the reverse of the inspection and working gages, as, for example, thread ring gages which are used for plug thread gages. All snap gages gaging below ¼ inch, and those so designed that they cannot be checked by ordinary measurements, should be provided with checks that are the reverse of the inspection gage itself. Master gages are of double importance to the manufacturer who

has part of his product made outside of his plant, because occasions will arise when his own inspectors will reject work that the outside manufacturer claims to be correct. One set of masters should be kept at the outside manufacturer's plant and one at the home plant.

Master-Plate Locating Method. When it is necessary to machine two or more plates so that they are duplicates as to the location of holes, circular recesses, etc., what is known as a "master plate" is often used for locating the work on the lathe faceplate. This master plate contains holes which correspond to those required in the work, and which accurately fit a central plug in the lathe spindle, so that, by engaging first one hole and then another with the plug, the work, which is attached to the master plate, is accurately positioned for the various drilling, boring or turning operations.

Match-Plate Patterns. To expedite the molding, small patterns are often mounted on plates with the cope side of the pattern on one side of the plate and the drag on the other. Thus there is a series of patterns on one side of the match plate corresponding to half sections of the pieces to be cast. A second series of patterns, corresponding to the other half sections of the pieces is located on the other side of the match plate. The match plate is provided with eye-holes at each end to receive the guide pins on the flask.

In using a double-faced match plate for molding, the method of procedure is to put the match plate between the two halves of the flask. Sand is then rammed into the drag side of the flask, after which bottom boards are placed over the sand to prevent it from shifting when the mold is turned over. Sand is next rammed into the cope side of the flask. A cope board provided with a cup or button at the point of sprue is then placed on the sand, and the cope and drag are squeezed together. The cope is next lifted off the match plate after which the match plate is lifted off the drag. After the necessary hand work has been done in finishing the two halves of the mold, the cope side is placed on the drag, and the mold is ready to have the molten metal poured into it.

For many classes of work there is no better form of pattern than the double-faced match plate. A pattern of this type has all the advantages possessed by the so-called "gate of patterns" in that it allows a number of castings to be poured simultaneously, and in addition it provides a simpler means of making the molds. Double-faced match plates can be used either where the sand is rammed in the flask by hand, where a manually operated squeezer is employed, or where a power-driven jolt squeezer is used in the foundry. This type of pattern will usually be found to give the maximum results obtainable with any of these methods.

Mathematical Symbols. The symbols used in formulas, as well as in algebra in general, are mainly the letters in the alphabet. Letters from the Greek alphabet are frequently used to designate angles, and the Greek letter π (pi) is always used to indicate the ratio between the circumference and the diameter of a circle; π, therefore, is always, in mathematical expressions, equal to 3.1416. The Greek letters most generally used, besides π, are α (alpha), β (beta), γ (gamma), δ (delta), θ (theta), μ (mu), ϕ (phi), and ω (omega). In general, any letter may be used as a symbol for any quantity. Ordinarily, however, the letters at the beginning of the alphabet are used as symbols for *known* quantities, and letters at the end of the alphabet as symbols for *unknown* quantities; thus, in general, a, b, c, etc., would be known, and x, y, z, t, u, etc., unknown quantities. There are, however, a few symbols that are almost universally used to designate, at all times, certain fixed quantities. The most common of these follow: n, any number in general (thus a^n = nth power of a); d, differential (in calculus); e, base of hyperbolic logarithms (2.71828); g, acceleration due to gravity (32.16 feet per second); i, imaginary quantity ($\sqrt{-1}$); t, time; v, velocity; $\triangle$ (delta), difference; δ (delta), differential; μ (mu), coefficient of friction; Σ (sigma), sign of summation; ω (omega), angles measured in radians. There are also a number of expressions in the form of symbols generally used in mathematics, as follows: $a^2 = a$ squared (2d power of a); $a^3 = a$ cubed (3d power of a); a^4 = 4th power of a; $\sin^{-1} a$ = arc, the sine of which is a; arc sin a = arc, the sine of which is a; $(\sin a)^{-1}$ = reciprocal of sin a $= 1 \div \sin a$.

Matheson Joint. The pipe joint known as the "Matheson joint," used for wrought-iron pipe, is made by enlarging one end of the pipe to form a suitable recess for lead, similar to the bell-end of a cast-iron pipe. This recess then receives the spigot end of the next pipe. The joint is practically of the same style as the joint generally used for cast-iron pipe.

Matte. Matte, also known as coarse metal, is a mixture of copper and iron sulphide obtained in the smelting of copper ore in a blast or reverberatory furnace.

Matter. Matter may be defined as anything that occupies space and possesses mass, or is acted upon by gravity. According to the atomic theory, matter is made up of molecules and atoms. The molecule is the basic unit of any element or compound, which retains the chemical properties of the substance in the mass. It is also the smallest division that can be conceived of as made by mechanical means, and is, therefore, taken as the physical unit. Molecules are, however, supposed to be made up of other particles

called atoms, which, in turn, are thought to be composed of exceedingly small particles called protons and electrons. See Electron Theory.

Forms of Matter: When the molecules of a substance are of the same kind, the force that holds them together is termed "cohesion"; when the molecules are unlike, the binding force is termed "adhesion." The accepted theory is that the molecules of every substance are in a state of constant motion and the amount of this motion determines the form of the substance. When the motion is so great that the attractive force is almost entirely overcome, the molecules appear to repel one another, and fly apart, filling every portion of the space within which they are contained; the matter is then said to be a gas. It has been calculated that at ordinary temperatures the average velocity of the molecules in the air is about that of a rifle bullet as it leaves the gun. Ordinary gases, such as oxygen, hydrogen and nitrogen, are invisible. Although the term "vapor" is frequently given to all gases, it is usually restricted to the gaseous form of substances that at ordinary temperatures and pressures are liquids or solids. When there is less motion, the attractive force holds the molecules loosely together and the body is said to be a liquid. In this state, the molecules readily change their relative positions, and, therefore, retain no definite form except that determined by the containing receptacle. When the motion is very small, the attractive force is so strong that the molecules are held quite closely together and the substance is said to be a solid.

Although it is common to classify each substance as a solid, a liquid or a gas according to that state in which we usually find it, this "natural" form will change under the proper conditions of temperature and pressure. Thus, everyone is familiar with water changing to ice or steam. Dry packed ice cream has acquainted many people with the solid form *(dry ice)* of the gas, carbon dioxide. Hypersensitization of photographic films has made others aware that the metal, mercury, vaporizes. More unusual and difficult changes of state are accomplished in the laboratory where extreme temperatures and pressures can be produced.

Matter was formerly thought to be indestructible, but energy and matter are now considered to be interconvertible. That is, under certain conditions, matter may disintegrate and lose some of its mass as energy and under other conditions energy may actually be formed into matter.

Maximum Shear Theory. This theory states that the cause of an elastic limit and the criterion for the beginning of failure is the sliding of particles past each other due to shear, and that failure in ductile materials is due to this sliding and not to direct tension. Hence, any case of direct tension or compression pro-

duces a tendency to slide and the failure is due to this. According to some investigators, the maximum shear theory should be adopted to the exclusion of the maximum strain and maximum stress theories since it shows that failure by tension and failure by compression are really only different aspects of failure by shear. Failure means the beginning of sliding which is not recovered when the stress is removed and gives permanent set, thus indicating the "elastic limit." It follows, therefore, that the elastic limit will be the same for tension as for compression. This is true for steel and other ductile materials and is in itself a point of evidence in favor of the maximum shear theory. Cast iron has no elastic limit and the actions referred to do not occur, so that elastic failure does not exist in cast iron as called for by the maximum shear theory. See Stress Theories.

Maximum Strain Theory. According to the maximum strain theory of St. Venant, failure occurs when the maximum unit deformation or strain in the piece reaches a certain critical value; hence, the stresses as measured by deformation or the "true stresses" should be considered. In other words, this theory supposes that the thing which causes failure and which must be used as a criterion for safety is the amount of deformation or strain. See Stress Theories.

Maximum Stress Theory. The maximum stress theory supposes that failure and elastic limit are purely matters of stress in a given direction regardless of the existence of stresses in other directions. That is to say, if a stress of 30,000 pounds is the elastic limit for a simple stress in a testing machine, it will also be the elastic limit in any case of compound stresses if the stress in one direction is 30,000 pounds and regardless of the existence of lesser stresses, whether tension or compression, in directions at right angles. See Stress Theories.

Maxwell. The "maxwell" is the unit of magnetic flux and is sometimes called a "field line."

As an electromagnetic unit, it is defined as $\frac{1}{4\pi}$ times the electromagnetic unit of magnetic quantity. This latter is defined as that magnetic quantity, which, when concentrated at a point and placed at a distance of one centimeter from an equal magnetic quantity also concentrated at a point, will experience a mechanical force of one dyne in free space.

As an electrodynamic unit, a maxwell is defined as the magnetic flux represented by a uniform magnetic induction of one gauss over an area of one square centimeter perpendicular to the direction of magnetic induction.

Mayari R. Low-alloy structural steel developed with a view to combining strength, good hot- and cold-working properties, good welding characteristics, little tendency to harden on rapid cooling, and high resistance to atmospheric corrosion. Has a minimum tensile strength of 65,000 pounds per square inch, and a minimum yield point of 50,000 pounds per square inch. Is about six times as corrosion-resistant as ordinary structural steel. Contains small percentages of chromium, nickel, and copper. Suitable for any purpose where ordinary structural steel is employed, but where the increased strength, better welding characteristics, and higher resistance to corrosion are especially desirable.

Mean Effective Pressure. The *effective* pressure acting against the piston of a steam engine, is the difference between the pressure on the steam side of the piston and that on the exhaust side, or, in other words, the difference between the working pressure and the back pressure. This value varies throughout the stroke with the expansion of the steam. The mean effective or average pressure (M.E.P.) is obtained from an indicator card and is used to determine the *indicated horsepower* of an engine.

Measurement, Absolute System. See Absolute System of Measurement.

Measuring Machines. The measuring machine is an instrument of great precision that is used for measuring standard lengths and for verifying the accuracy of reference gages. The ordinary type of measuring machine is provided with a rigid cast-iron bed upon which is mounted two heads, each of which contains a spindle that is placed in contact with the part to be measured. One head is equipped with a micrometer screw and a large graduated wheel or dial which indicates length variations within a limited range. For greater lengths, one head is moved along the bed the required distance. This movable head may be set by simply placing a standard end-measuring gage of known length between the contact points, or it may be set by reference to a standard bar forming part of the machine. Such a bar has extremely fine division lines which are equally spaced and enable the head to be accurately set by observing the lines through a suitable microscope. Another feature common to high-grade measuring machines is some form of mechanism for indicating the pressure of the contact or measuring points against the work, in order that slight errors will not be introduced in the measurements of duplicate parts, on account of minute variations in the pressure. Pressure indicating devices are made in several forms, such as a plug which drops from between points when a certain pressure is reached; a level which is inclined at an angle when acted upon by the moving contact point; and a spring-operated

plunger which is used in conjunction with a scale and hair-line microscope.

Mechanical Draft. Mechanical draft is often employed as a substitute for a tall chimney, and also in case a boiler plant is increased beyond the capacity of the original chimney. Again, certain kinds of low-grade fuels require a stronger draft than is provided by a chimney of ordinary height. Forced draft is also necessary for mechanical stokers of the under-feed type. In a general way, the advantages of mechanical draft are as follows: Increase of boiler capacity, as well as efficiency, which is due to the more intimate mixture of the air with the fuel, when under pressure, thus making it possible to carry deeper fires; ease of regulation, and the ability to provide just the right amount of air for complete combustion; the use of poorer grades of fuel than can be burned with a natural draft; and the possibility of forcing the boilers, if necessary, without regard to outside weather conditions. Forced draft also permits the use of feed-water heaters in the smoke flues, which cool the chimney gases to a comparatively low temperature, and which would interfere with the natural draft of a chimney. The cost of the equipment for mechanical draft is also considerably less than for a chimney.

Mechanical Drawing Principle. See Projection.

Mechanical Efficiency. See Efficiency of Mechanism.

Mechanical Equivalent of Heat. This is an expression used to designate the number of foot-pounds of mechanical energy equivalent to one British thermal unit. The mechanical equivalent of heat equals 778 foot-pounds.

Mechanical Mixture. A mechanical mixture is a substance composed of two or more other substances which are not combined chemically with each other; the particles of each ingredient can be identified and separated by mechanical means. See also Compound.

Mechanical Powers. The five "mechanical powers" were defined in the old books on mechanics as the lever, the screw, the wedge, the inclined plane and the pulley. The wedge, the inclined plane and the screw are the same in principle. A screw is simply a cylinder with an inclined plane wrapped around it and, of course, an inclined plane and a wedge are the same. The pulley is but another form of the lever; hence, there are really only two so-called mechanical powers: the lever and the wedge or inclined plane.

Mechanical Stokers. A material saving in labor can usually be effected by the installation of mechanical stokers in large and

medium-sized power plants, as compared with hand firing. The cost of maintenance and initial cost of grates for hand firing is less than for mechanical stokers, but the coal is fed uniformly by mechanical stokers, which insures constant temperature and steaming. With hand-fired boilers, the furnace doors are opened frequently, which tends to chill both the fire and the furnace setting and is conducive to the production of smoke. Unless skilled firemen are employed, the efficiency of the hand-fired boiler will be lower, because of the greater heat content in the ash, holes in the fire bed, etc. Skilled firemen are also essential for mechanical stokers; but there are not so many required, and the men have more time to use efficient firing methods. Mechanical stokers may be divided into three general classes: The *chain-grate* stoker, which carries the green coal in the combustion chamber on a horizontal surface and depends upon the reflected heat from the brick arch above it to ignite it; the *inclined-grate* or *over-feed* stoker, which depends on the green coal feeding down over the fire bed, and the *under-feed* stoker, which forces the green coal in under the fire bed and utilizes forced draft. There are numerous designs of each of these classes.

Medium Pressure. The expression "medium pressure," when applied to valves and fittings, means suitable for a working pressure of from 125 to 175 pounds per square inch.

Meehanite Metal. The special cast iron known as "Meehanite" has a number of important physical properties. The basic methods of manufacture are similar to those used for cast iron and semi-steel in that the basic materials employed are pig iron, foundry scrap, steel scrap, coke, and limestone. The cupola, however, is of different design, and the method of melting is under strict metallurgical control.

Physical Properties: For general engineering applications, Meehanite metal is made in different types, designated as A, B, C, D, E, Super A and Super WH. These types vary in tensile strength from 30,000 pounds for the E grade to 50,000 pounds per square inch for the A grade. By heat-treating the A grade, a tensile strength of 75,000 pounds per square inch can be obtained.

Meehanite metal known as Super A, provides a great increase in hardness and wearing qualities, accompanied by an actual improvement in machinability. For example, Super A Meehanite with a hardness of 269 Brinell machines 20 per cent faster than alloy cast iron of 207 Brinell. The metal has a high modulus of elasticity, a good degree of toughness, and a tensile strength in excess of 50,000 pounds per square inch.

Meehanite alloy Super WH is unusually wear resistant and possesses a good combination of physical properties. It can be produced with a hardness up to 578 Brinell.

In addition to improved tensile strength, Meehanite metal has many other unusual physical characteristics. It is "non-growing" at high temperatures, and offers a high resistance to abrasion, erosion, and corrosion. Its soundness and reliability are marked, and Meehanite castings are uniform and freely machined.

Applications: Meehanite has been applied in the automobile industry for cast camshafts and crankshafts, as well as for other castings. The density of the metal, or its pressure tightness, has made it of value in laundry machinery—for steam drying and pressing machines—where castings must be impervious to high-pressure steam. The metal acquires a high degree of polish, and can be readily chromium-plated, as well as finished by other protective surface finishes.

One application in which the metal has been found of particular value has been for the cylinders and rams of hydraulic presses used in forging, pressing, or deep drawing work. Because of the occasional overloads to which they are subjected, castings for these services are severely tested. The combination of high-pressure resistance and the ability to take a mirror-like finish in the bore of cylinder castings has made this material well suited for hydraulic cylinders used in the operation of modern machine tools.

Super A is an alloyed Meehanite, in which copper is used largely as the base alloy. It has been found particularly well adapted to the construction of internal combustion engines, marine cylinders, and machinery of the type in which smooth running qualities are of primary importance. It is also used in the manufacture of large gears, piston-rings, and other parts that operate under severe wearing conditions. Super WH has been found practical for castings subjected to extremely severe wear, such as ball-mill liners, muller tires, and pan bottoms.

The resistance to growth of Meehanite under either continuous high temperatures or alternating high and low temperatures has established it as an essential material in many industrial furnace and high-temperature applications.

In pumping machinery in gravel, cement, mining, crude oil, and chemical plants, the resistance of this metal to abrasion and corrosion is one of its most valuable characteristics. It is also used for conveyor chains, dredger bucket lips, and similar applications.

Application to Dies: The wear resisting property of Meehanite has given it an important place in the making of dies for forming, pressing, drawing, and stamping metal. By virtue of its hard, tough, and dense structure, the metal does not crush, at

its edges nor deform or gall, but, on the contrary, work-hardens on the surface, acquiring a glazed skin which greatly increases the life of the die.

Megadyne. Megadyne is a unit of force in the absolute system of measurement, equal to 1,000,000 dynes.

Meltomatic. A paste solder that can be brushed on any metal and heated by any means to its melting temperature, which is slightly above 400 degrees F. No preliminary cleaning or tinning operations are necessary. Especially applicable where soldering irons are difficult to use, as in inaccessible spaces and on small parts.

M.E.P. An abbreviation commonly used for Mean Effective Pressure.

Mercury. Mercury, also known as quicksilver, is used mainly in the manufacture of fulminate for explosive caps, of drugs, of electric appliances, of alloys or amalgams, and of scientific apparatus, and, to a diminishing degree, in the recovery of precious metals, especially gold. Mercuric oxide (red oxide of mercury) is the active poison in antifouling paint used on ship's bottoms. Mercury dissolves a great many of the metals, forming with them alloys which are known as *amalgams*. Mercury occurs in nature mainly in the form of a red sulphide called "cinnabar" (HgS). Mercury is one of the metallic chemical elements, the symbol of which is Hg, and the atomic weight, 200.6. This metal is fluid at ordinary temperatures. It becomes a solid at —39 degrees C. (—38 degrees F.), and boils at 357 degrees C. (675 degrees F.). Mercury is one of the heavier metals, its specific gravity being 13.6, making the weight per cubic inch close to one-half pound. Its electric conductivity is low, being only about 1.75 (silver = 100). Its specific heat at 32 degrees F. equals 0.033, and its heat conductivity, 1.48 (silver = 100).

Mercury Deposits. The largest and richest known deposits of mercury in the world are located in central Spain, and there are large deposits in California and Texas. Deposits are also found in Russia, Bavaria, Hungary, Italy, Mexico, and Peru. The Spanish deposits have been mined almost continuously since the early Roman Empire, and have been owned and worked by the Spanish Government since 1645.

Mercury Vapor Lamps. See Vapor Lamps.

Mercury-Vapor Power Generation. In the Emmet mercury-vapor process mercury is vaporized in a boiler at temperatures which can be much higher than those which are practicable with steam. It is then carried through a turbine and does useful

work, exhausting into a surface condenser where its latent heat is used to make steam at pressures desirable for use. The condensed liquid is carried back to the boiler preferably by gravity. The characteristics of mercury are such that high temperature can be used without excessive pressure, and the heat of condensation can be delivered at a convenient degree of vacuum and at a temperature suited to making steam at pressures desirable for power uses. The process thus affords means by which the temperature ranges practicable with steam are greatly increased under conditions which afford large gains in efficiency of conversion of the heat energy of fuel into work.

The most difficult and novel part of this process is the boiler. While mercury is a good heat conductor, it does not wet steel and considerable temperature differences are required to deliver heat to it at a high rate. When it begins to produce vapor on the heating surfaces this condition becomes rapidly worse. Successful mercury boilers are dependent upon a rapid circulation of the liquid and the large difference of pressure between the top and the bottom which prevents boiling of the circulating liquid until it is well started on its upward course. That is, the rapid heat delivery must be confined to the part of the surface which is not much disturbed by boiling. Rapid circulation is essential and the spaces for discharging vapor must be so proportioned that the circulation will not be checked by the escape of the vapor. If these spaces are too small the liquid will be given motion like a charge of shot, and prohibitive back pressure will result which will check circulation. The vapor must slip by the liquid, impelling it but not giving it too much velocity. Probably the most economical method of operating this process is to get as much heat as possible into the feedwater by bleeding the steam turbines as in modern steam practice.

Messenger Strand. A messenger wire or strand is a wire or cable strung along with and supporting wires, cables, or other conductors for electric current. A seven-wire galvanized strand is used for supporting lead-covered telephone cables. The heavy lead-encased telephone wire cables are not, in themselves, sufficiently strong to withstand the strain incidental to stringing those cables between poles a considerable distance apart. A wire rope of 5/16, ⅜, or 7/16 inch diameter, known as "messenger strand," is, therefore, strung between the poles, and the heavy telephone cable is suspended from this by means of clips, wire, or cord at short intervals.

Extra-galvanized cables of Siemens-Martin steel strand, high-strength crucible steel strand and extra-high-strength plow steel strand are also used for the catenary suspension of electrical conductors.

Metacenter See Buoyancy.

Metal. A metal is a chemical element which generally has a peculiar luster, known as "metallic" luster, is electropositive, is a conductor of heat and electricity, and usually occurs in nature in the form of compounds called ores. There is no very definite line drawn between the metals and non-metals. The elements which are not definitely classified as either the one or the other are known as "metalloids."

Metallic Packing. Metallic packing is extensively used on steam engines to prevent any leakage of steam past the piston and valve stem, as it is much more durable than any fibrous packing, if the composition of the packing rings is correct and it is properly applied.

Metallography. The science or study of the microstructure of metal is known by most metallurgists as "metallography." The name "crystallography" is also used to some extent. The examination of metals and metal alloys by the aid of the microscope has become one of the most effective methods of studying their properties, and it is also a valuable means of controlling the quality of manufactured metallic articles and of testing the finished product. In preparing the specimen to be examined, a flat surface is first formed by filing or grinding, and this surface is then given a high polish, which is later subjected to the action of a suitable acid or etching reagent, in order to reveal clearly the internal structure of the metal when the specimen is examined under the microscope. This process shows clearly to an experienced observer the effect of variation in composition, heat-treatment, etc., and in many cases it has proved a correct means of determining certain properties of industrial products that a chemical analysis has failed to reveal.

Preparing Hardened Steel for Microscopic Study: To cause the constituents of the specimen to contrast with one another as seen through the microscope is the desired end, and a reagent is used which acts differently towards these elements; generally this reagent acts on one element more than on another so that the one least affected reflects the light from the faces of its crystals while the etched part absorbs the light, and, therefore, appears dark when photographed.

In etching specimens to develop the constituents of hardened and tempered steels, very good results are obtained with sulphurous acid that is composed of 4 parts of sulphur dioxide to 96 parts of distilled water. The specimens are immersed in this, face upward, and removed as soon as the polished surface is frosted. This takes from 7 seconds to 1 minute. They are then rinsed with water and dried with alcohol. Very thin layers of iron sulphide

are deposited on the different constituents in different thicknesses, and this gives them different colors. Austenite remains a pale brown; martensite is given a pale blue and deep blue and brown color; troostite is made very dark; sorbite is uncolored; cementite exhibits a brilliant white; and ferrite is made dark brown. When the etching has proceeded to the desired extent, the specimen is at once washed thoroughly in order to remove all trace of the etching reagent. Usually it is simply rinsed with water, but frequently the washing is done with absolute alcohol, while ether and chloroform are also sometimes used.

The apparatus used for examining the etched surfaces of metals is composed of a microscope and camera combined with an arc lamp or other means of illumination.

Microscopic Study of Steel: Steel, in particular, shows many changes of structure due to the mechanical and thermal treatment, so that the microscope has become a very valuable instrument with which to inspect steel. To one who understands what the different formations of crystalline structure denote, the magnified surface reveals the temperature at which the steel was hardened, or at which it was drawn, and the depth to which the hardness penetrated. It also shows whether the steel was annealed or casehardened, as well as the depth to which the carbon penetrated. The carbon content can be closely judged, when the steel is annealed, and also how much of it is in the graphitic state in the high carbon steels. The quantity of special elements that is added to steel, such as nickel, chromium, tungsten, etc., can also be estimated, when the alloy to be examined has been put through its prescribed heat-treatment. Likewise, the impurities that may be present are clearly seen, regardless of whether they are of solid or gaseous origin.

Metalloids. Metalloids are chemical elements on the borderline between the two main classes of elements—metals and nonmetals. The metalloids as a rule resemble metals in their physical properties and non-metals in their chemical properties.

Metallurgy. The art of extracting metals from their ores is, in general, known as *metallurgy,* but the term has, by custom, been restricted to the commercial methods used, as opposed to those which are employed only in the laboratory. When the metals are extracted from their ores by means of electrical processes, the art is known as *electrometallurgy.* Briefly stated, the metals are obtained from their ores by one of three methods: 1. By being exposed to the action of fire in the presence of a flux, so as to burn away certain components of the ore, or deoxidize ("reduce") it. 2. The ore may be amalgamated by mercury, so that the metal is obtained as an amalgam, which can be separated mechanically from the dross. The purified amalgam is distilled and the

mercury is recovered as a distillate, while the metal remains. 3. The wet process, in which the metal is extracted either from the natural ore or from the ore after it has been roasted, by means of an acid or salt solution, and precipitated from this solution by some suitable reagent. All of these methods generally yield an impure product, which must be refined before it becomes a commercial market product.

Metal Spinning. See Spinning Metals.

Metal Spraying Process. In the application of this process, a metal spraying "gun" is used to deposit either ferrous or nonferrous metals upon metallic or other surfaces. The object may be to build up worn or under-sized parts, provide wear-resisting or corrosion-resisting surfaces, correct defective castings, etc. Nonferrous metals may be applied to ferrous metals, or vice-versa, and metallic coatings may also be applied to non-metallic materials such as glass, porcelain, stone, brick, concrete or leather. Any metal obtainable in wire form may be utilized and in some cases, the material to be sprayed is in the form of rods. The wire is fed automatically through the nozzle of the gun, then gas, oxygen, and compressed air serve to melt and blow the atomized metal against the surface to be coated. As the metal impinges against the surface at high velocity, it solidifies and forms a homogeneous bond with the surface. The gas used may be acetylene, propane, natural gas, butane, or coal gas. Any desired thickness of metal may be deposited and the metals include steels ranging from low to high carbon content, various brass and bronze compositions, babbitt metal, tin, zinc, lead, nickel, copper, and aluminum. The movement of the spray gun, in covering a given surface, is either controlled mechanically or by hand. In enlarging worn or under-size shafts, spindles, etc., it is common practice to clamp the gun in a lathe toolholder and use the feed mechanism to traverse the gun at a uniform rate while the metal is being deposited upon the rotating work-piece. The spraying operation may be followed by machining or grinding to obtain a more precise dimension. Cold drawn steel or brass shafts or rods may be covered with high-carbon steel, stainless steel, or monel metal to provide wear or corrosion resisting surfaces. Pitted valve seats may be resurfaced, blow holes in castings filled, parts zinc coated to prevent corrosion, over-sized bores reduced, and there are numerous other applications of the metal spraying process. See also Plasma-Flame Metal-Spraying.

Meter Equivalent in Light Waves. See Light Wave as Length Standard.

Meter-Kilogram. This is a unit of work in the metric system, designating the work required to raise one kilogram to a height of one meter; 1 meter-kilogram = 7.233 foot-pounds.

Meters, Ampere-Hour. See Ampere-hour Meters.

Meters and Instruments. Although the terms "instruments" and "meters" are frequently used synonymously in referring to electrical measuring devices, the meter departments of manufacturing and operating companies commonly use the word "meters" in the collective sense to designate only those devices which register the total energy or quantity of electricity consumed in or supplied to a circuit, and reserve the term "instruments," in the collective sense, for all other electrical measuring or indicating devices.

Methods-Time Measurement: Methods-time measurement is a procedure which analyzes any manual operation or method into the basic motions required to perform it, and assigns to each motion a predetermined time standard which is determined by the nature of the motion and the conditions under which it is made.

The basic motions have been standardized by the MTM Association for Standards and Research and are given as: reach; move; turn; apply pressure; grasp; position; release; disengage; eye motions; and body, leg, and foot motions.

Time standards have been determined by careful study of motion pictures. The film speed in the original research was 16 frames per second (0.00001737 hour per frame) from which evolved the Time Measurement Unit (TMU) which equals 0.00001 hour or 0.0006 minute or 0.036 second. Conversely 1 hour equals 100,000 TMU, 1 minute equals 1,667 TMU, and 1 second equals 27.8 TMU.

On an application—data card, which the MTM Association publishes, specific times in TMUs are given for the basic motions. See also Time Study.

Metric Horsepower. The unit of power adopted for engineering work, as defined in the English system of measurement, is equal to 33,000 foot-pounds per minute, or 550 foot-pounds per second. The metric horsepower, used in countries where the metric system is employed, is equal to 75 kilogram-meters per second, which is only 32,550 foot-pounds per minute, or 542.5 foot-pounds per second. Hence, it is evident that the metric horsepower is about 1.5 per cent smaller than the horsepower employed in the countries using the English system of measurements.

Metric System. In the metric system of measurements, the principal unit for length is the meter; the principal unit for capacity, the liter; and the principal unit for weight, the gram. The following prefixes are used for subdivisions and multiples: milli = 1/1000; centi = 1/100; deci = 1/10; deca = 10; hecto = 100; kilo = 1000. In abbreviations, the subdivisions are frequently used with a small letter and the multiples with a capital letter, although this practice is not universally followed everywhere where the metric system is used. All the multiples and subdivisions are not used commercially. Those ordinarily used for length are kilometer, meter, centimeter, and millimeter; for capacity, square meter, square centimeter, and square millimeter; for cubic measures, cubic meter, cubic decimeter (liter), cubic centimeter, and cubic millimeter. The most commonly used weights are the kilogram and gram. The metric system was legalized in the United States by an Act of Congress in 1866.

Metric Measures of Length: 10 millimeters (mm.) = 1 centimeter (cm.); 10 centimeters = 1 decimeter (dm.); 10 decimeters = 1 meter (m); 1000 meters = 1 kilometer (Km.).

Metric Measures of Weight: 10 milligrams (mg.) = 1 centigram (cg.); 10 centigrams = 1 decigram (dg.); 10 decigrams = 1 gram (g.); 10 grams = 1 decagram (Dg.); 10 decagrams = 1 hectogram (Hg.); 10 hectograms = 1 kilogram (Kg.); 1000 kilograms = 1 (metric) ton (T.).

Metric Weight Equivalents: 1 metric ton = 0.9842 ton (of 2240 pounds) = 2204.6 pounds; 1 kilogram = 2.2046 pounds = 35.274 ounces avoirdupois; 1 gram = 0.03215 ounce troy = 0.03527 ounce avoirdupois; 1 gram = 15.432 grains.

Metric Translating Gears. See Translating Gears.

Mica. There are two industrial varieties of mica. One is "muscovite" (commercially known as rum, ruby, smoked, or green, according to its color) and the other "phlogopite" (amber). Only muscovite is mined on an extensive scale in the United States. Phlogopite comes from Canada and India, large quantities being imported into the United States. The chief mines in the United States are in North Carolina. The most extensive application of mica is for electrical purposes, because it is one of the best insulators available. The fact that it is able to withstand high temperatures also makes it valuable as an insulating material for electrical machinery. The laminas of mica are generally separated and sorted into various grades of purity, and are then cemented together to form plate or flexible reconstructed mica of any required thickness or purity. Mica is extremely complex and variable in composition. It generally consists of an anhydrous silicate of aluminum together with potash or sodium.

Mica is characterized by a very easy cleavage in a single direction, and by a high degree of flexibility, elasticity, and toughness.

Mica Insulation of Commutators. See Commutator Insulation.

Micarta. Micarta is a non-metallic laminated product of specially treated woven fabric. By means of the various processes through which it is passed, it becomes a homogenous structure with physical properties which make it especially adapted for use as gears and pinions. Micarta can be supplied either in plate form or cut into blanks. It may also be molded into rings or on metal hubs for applications such as timing gears, where quantity production is attained.

Micarta gears do not require shrouds or end plates except where it is desired to provide additional strength for keyway support or to protect the keyway and bore against rough usage in mounting drive fits and the like. When end plates for hub support are employed they should extend only to the root of the tooth or slightly less.

Properties: The physical and mechanical properties of Micarta are as follows: Weight per cubic inch, 0.05 pound; specific gravity, 1.4; oil absorption, practically none; shrinkage, swelling or warping, practically none up to 100 degrees C.; coefficient of expansion per inch per degree Centigrade, 0.00002 inch in the direction parallel to the laminations (edgewise), 0.00009 inch in the direction perpendicular to the laminations (flatwise); tensile strength, edgewise, 10,000 pounds per square inch; compressive strength, flatwise, 40,000 pounds per square inch; compressive strength, edgewise, 20,000 pounds per square inch; bending strength, flatwise; 22,000 pounds per square inch; bending strength, edgewise, 20,000 pounds per square inch. Micarta may be machined in the ordinary manner with standard tools and equipment.

Micarta Machining. In cutting blanks from sheets of "micarta" a band saw running at a speed of 350 revolutions per minute has been found suitable. The saw should be of the bevel-tooth type, seven teeth to the inch. For large quantities a trepanning tool should be used. In trepanning blanks, the tool should be fed so as to cut part way through all of the "layouts"; then the micarta plate should be turned over, and the cutting completed from the reverse side.

Turning tools should be of high-speed steel cutting at speeds similar to those used for bronze or cast iron. If two cuts are taken, about 0.010 inch of stock should be left for the finishing cut.

Drilling at right angles to the layers is done with a standard drill, which should be backed off sufficiently to provide plenty of

clearance. When drilling parallel to layers, a "flat" or "bottom" drill should be used. In rough-drilling, the hole should preferably be drilled partly through the material from each side to prevent possible splitting as the tool protrudes. If this is impracticable, the hole can be drilled all the way through the material, provided the material is "backed up" with wood, stiff cardboard, or any other material that is sufficiently rigid to support the under surface at the point where the drill comes through.

The methods described for drilling apply as well to tapping, except that when the tapping is done parallel to the layers, it is advisable to clamp the material to equalize the stress on the layers and prevent possible splitting.

In milling, a standard tool may be used at a speed and feed corresponding to that used in working bronze or soft steel. The cutting angle of the cutter will give better results if ground with a slight rake.

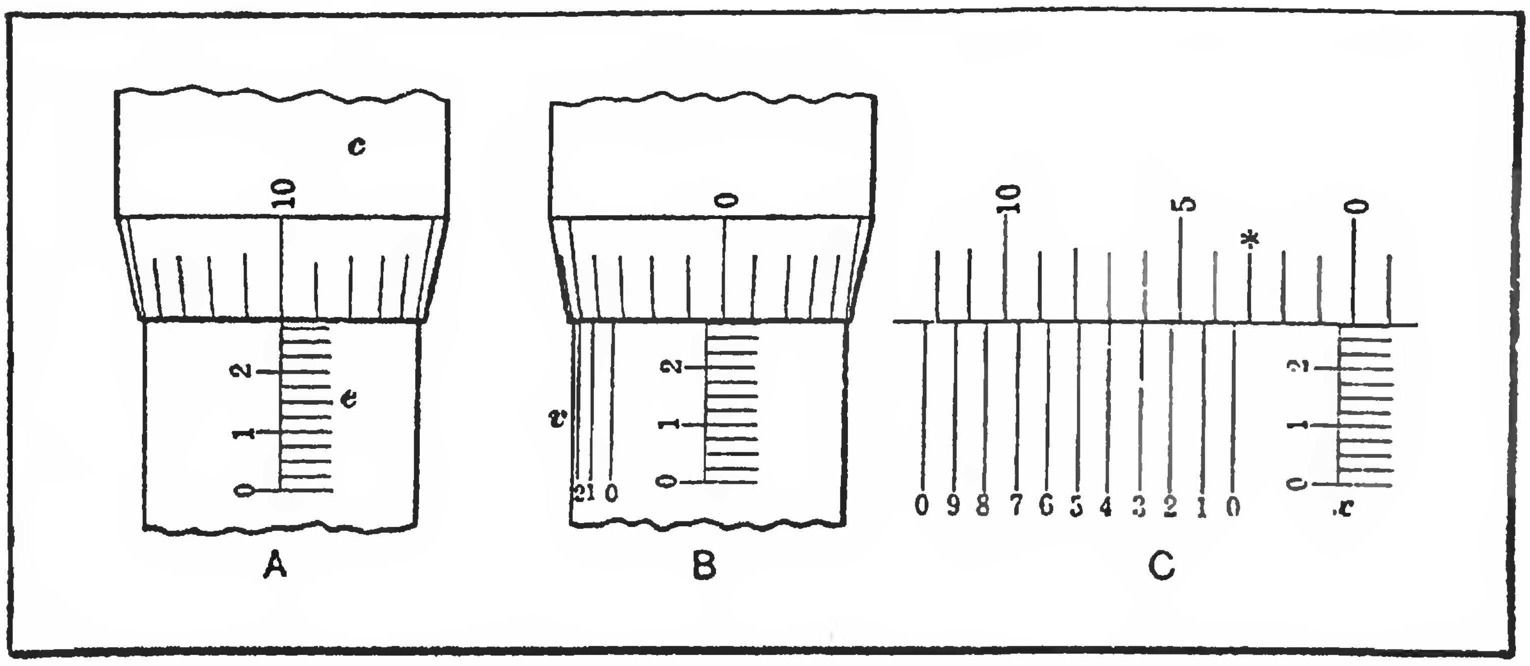
While there is a wide range of practice as to feeds and speeds in cutting gears on hobbing machines, a hob speed of not less than 140 revolutions per minute, has given satisfaction. In machining gear teeth on a gear shaper, a speed of about 100 to 130 strokes per minute with a fairly fine feed has given good results. Backing-up plates should be used in machining micarta gears.

Mico-Iron. Mico-iron is an iron of close grain and uniform texture. It can be machined readily, and surfaces requiring long life can be chilled without affecting the machinability of other surfaces. The tensile strength of "Mico" cast iron is from 32,000 to 35,000 pounds per square inch.

Micro-inch. One millionth inch or 0.000001 inch.

Micrometer. Micrometer calipers are precision measuring instruments that are equipped with a screw of fine pitch and graduations which show slight movements of the screw so that accurate measurements can be taken. The pitch of the thread on the spindle of an ordinary micrometer is 1/40 of an inch. Along the frame at *e* (see diagram *A*), there are graduations which are 1/40 inch apart; therefore, when thimble *c* and the measuring spindle are turned one complete revolution, they move in or out a distance equal to one of the graduations, or 1/40 inch, which equals 25/1000 inch. If, instead of turning one complete revolution, the thimble is turned, say, 1/25 of a revolution, the distance between the anvil and the end of the spindle will be increased or diminished 1/25 of 25/1000 of an inch, or one thousandth inch; therefore, the beveled edge of a micrometer spindle has twenty-five graduations, each of which represents 0.001 inch. Some micrometers have a vernier scale *v* on the frame, as shown at *B*,

in addition to the regular graduations, so that measurements within 0.0001 inch can be taken. Micrometers of this type are read as follows: First determine the number of thousandths, as with an ordinary micrometer, and then find a line on the vernier scale that exactly coincides with one on the thimble; the number of this line represents the number of ten-thousandths to be added



Micrometer Graduations

to the number of thousandths obtained by the regular graduations. The relation between the graduations of the vernier and those on the thimble is more clearly shown by diagram *C*.

Micrometer Caliper's Origin. Evidence which is now available shows that credit for the origin of the micrometer caliper must be largely accorded to a French inventor and machinist by the name of Jean Laurent Palmer, who was working at the time in Paris. Palmer's "screw caliper," as he called it, was patented in France on September 7, 1848, and was manufactured under the name of the "Systeme Palmer." There did not seem to be any general appreciation of the importance of this tool until the year 1867, when it was seen by Joseph R. Brown and Lucian Sharpe, while on a visit to the Paris Exposition of that year. They were impressed with the possibilities of such a tool when properly made, and brought one back with them on their return to America. Soon after, they commenced the manufacture of a small-sized micrometer, suitable for measuring sheet metal and wire, placing it on the market in 1869 under the name of the "pocket sheet-metal gage." The introduction of the 1-inch micrometer caliper followed that of the pocket sheet-metal gage, and it was shown in the Brown & Sharpe catalogue of 1877, and for the first time, the name "micrometer caliper" was used.

Micron. One millionth meter (0.00003937 inch).

Micro-Photography. See Photomicrography and also Metallography.

Microscope, Toolmaker's. See Toolmaker's Microscope.

Microscopic Examination of Steel. See Metallography.

Mil and Circular Mil. The *mil* is used in the measurement of the diameters and areas of electric wires, and the thicknesses of electrical insulating materials. A mil equals 0.001 inch. A *circular mil* is the area of a circle 0.001 inch in diameter. See also Circular Mil.

Mile. One mile = 1760 yards = 5280 feet = 1.609 kilometers = 1609 meters. As a surveyor's length measure, one mile = 8 furlongs = 80 chains = 1760 yards = 5280 feet. A nautical mile, sometimes incorrectly called "knot," equals 1.1516 statute miles or 6080.26 feet. A *knot* is a measure of speed, and is equal to a speed of one nautical mile per hour.

Mill File. Mill files are parallel in thickness from the heel to the point and usually tapered so that the width at the end equals about three-fourths the width of the stock. The mill file is also made "blunt" or of equal width and thickness throughout its length. Quite a number of mill files having one round edge are used, and some are provided with two round edges. The teeth are ordinarily single-cut, bastard. This file is used in machine shops for lathe work, draw-filing, and, to some extent, for filing brass and bronze. It is also employed for sharpening metal saws, etc. The mill files of the round edge type are used for filing the gullet or space between saw teeth.

Milling, Continuous. See Continuous Milling.

Milling Cutters. As the processes of milling can be applied to an almost unlimited range of work, the cutters used on milling machines are made in a great variety of forms. Some of the different types can be used for general work of a certain class, whereas other cutters are made especially for milling one particular part. A cylindrical or plain cutter is used for producing flat surfaces and it is made in various diameters and lengths. Cutters having helical teeth are generally used in preference to the type with straight or parallel teeth, especially for milling comparatively wide surfaces, because the former cut more smoothly. Helical cutters also require less power for driving and produce smoother surfaces. Face mills which have cutters on the side or face are also used for milling flat surfaces.

A side milling cutter has teeth on both sides, as well as on the periphery, and it is used for cutting grooves or slots and for other

operations, examples of which will be shown later. Two side mills are often mounted on the same arbor and used in pairs for milling both sides of a part at the same time. This type of cutter is also employed in conjunction with other forms for milling special shapes. The inserted-tooth construction is used ordinarily for large cutters, in preference to the solid form, because it is cheaper, and the inserted teeth can readily be replaced when necessary. When solid cutters are made in large sizes, there is danger of their cracking while being hardened, but with the inserted-tooth type, this is eliminated.

End mills have teeth on the end as well as on the periphery or body; hence, they can cut in an endwise as well as a sidewise direction. These mills have taper shanks which are driven into a hole of corresponding taper in the machine spindle. The shanks have a flat end or tang which engages a slot in the spindle and prevents the mill from slipping when taking a cut. The larger sizes of end mills do not have solid taper shanks, but are made in the form of shells which are fastened to an arbor that serves as a shank. This type of cutter can often be used when a long arbor with an outboard support would be in the way. Formed milling cutters are made to the same shape as the profile of the piece to be milled.

Milling Cutters, Hand of. A cutter which rotates to the right (clockwise), as viewed from the spindle or rear side, is said to be right-hand, and, inversely, a left-hand cutter is one that turns to the left (counter-clockwise) when viewed from the spindle of the machine.

Milling Machine Lead. See Lead of Milling Machine.

Milling Machine Origin. The first practical machine for plain milling operations is said to have been built by Eli Whitney, well-known inventor of the cotton gin, about 1818. This machine, now in the possession of Yale University, is a small bench type. A solid wooden block forms the base of the Whitney milling machine and the supporting legs are made of wrought iron. The main spindle is driven directly by a belt pulley, and between the two main spindle bearings there is a double-grooved wooden pulley connecting with a smaller pulley on a worm-gear shaft of the feed mechanism. The worm of this shaft engages a worm wheel mounted upon the table feed-screw. This worm is held in engagement by a spring latch which permits disengagement for hand feeding. The worm shaft is pivoted at one end so that the worm could readily drop out of engagement.

Milling Machine, Standard Spindle. Standard spindle ends for milling machines have been adopted by the milling machine

manufacturers of the National Machine Tool Builders' Association. The tapering bore for receiving arbors or cutter shanks has a taper of 3½ inches per foot, this steep angle taper having been adopted to insure instant release of the arbor and eliminate sticking in the spindle. The large ends of the arbor holes have the following diameters: No. 30 taper, 1¼ inches; No. 40 taper, 1¾ inches; No. 50 taper, 2¾ inches; No. 60 taper, 4¼ inches. Arbors have also been standardized. This spindle-nose and arbor construction is covered by U. S. patents.

Milling Machines, Attachments. The range of a milling machine, or the variety of work it is capable of doing, can be greatly extended by the use of special attachments. Many of these are designed to enable a certain class of milling machines to perform operations that ordinarily would be done on a different machine; in other words, the attachment temporarily converts one type of machine into another. There are many different attachments for milling machines, some of which are very common, whereas others are rarely used in the average shop.

Vertical-spindle Attachments: Vertical attachments are used in connection with horizontal machines of the column-and-knee types, whenever it is desirable to have the cutter in a vertical or angular position. There are several types of vertical attachments designed for various classes of work. The principal difference between these designs, aside from minor details, is in the adjustment of the cutter spindle.

Compound Vertical-spindle Attachment: There is a compound type of vertical spindle attachment which is adjustable in two vertical planes, one being parallel with the axis of the spindle, and the other being at right angles to the spindle.

Universal Milling Attachment: The universal milling attachment is so named because the spindle can be set at any angle in both horizontal and vertical planes.

Spiral Milling Attachment: When milling a spiral, it is not always possible to align the cutter with the angle of the spiral by swinging the machine table around. The tables of most universal milling machines cannot be adjusted to an angle greater than about 45 or 50 degrees; hence, for greater angles it is common practice to leave the table in its normal position at right angles to the spindle of the machine, and to use an attachment for holding the cutter at the proper angle. What are known as spiral milling attachments are often used for this work, and they are so arranged that the cutter spindle may be swiveled to any angle in a horizontal plane.

High-speed Attachment: For some milling operations on such work as diemaking, etc., it is necessary to use a small cutter

which should be run more rapidly than the fastest spindle speed available, and, in order to obtain these high speeds, special attachments are sometimes used. These attachments consist principally of an auxiliary spindle that holds and drives the cutter, and suitable gearing connecting with the main spindle and so proportioned as to give the necessary increase of speed. The gearing and spindle are carried by a housing which is attached to the machine. High-speed attachments are used on both horizontal- and vertical-spindle machines.

Circular Attachment: A circular milling attachment has a round work table which can be rotated for milling circular surfaces or slots. This attachment, which is placed upon the main table of the machine, is either used on a vertical-spindle machine or in connection with a vertical-spindle attachment on a horizontal-spindle machine.

Milling Machines, Classification. The names used to designate different classes of milling machines may indicate some constructional feature that is characteristic, or they may relate to the nature of the work for which the machine is intended. There are a few exceptions to this method of classification, however, as special names are used to some extent; moreover, in some cases, manufacturers of milling machines do not use the same name for similar types of machines. The constructional features which are generally indicated by the name are the position of the spindle, the design of the bed or frame, and the arrangement of the work table. A great many milling machines have horizontal spindles, and some of them are known as *horizontal* types, but, in most cases, the name indicates some other constructional feature in order to distinguish between different classes having horizontal spindles. For instance, there are *plain* machines and *universal* machines; both of these types have horizontal spindles, but one is simpler in construction than the other and is not adapted to such a wide range of work A vertical milling machine has a vertical spindle; some special vertical milling machines, however, are named according to the class of work for which they are intended, as, for example, die-sinking and profiling machines, which are, in reality, special types of vertical spindle milling machines.

The frames of milling machines are usually of two general forms; the most common design is a vertical column which supports the horizontal cutter spindle, and has on the front face or side an adjustable knee upon which the work-table is mounted. This is known as the *column-and-knee* construction; several different types of milling machines are designed in this way. Other milling machines have beds or frames which extend horizontally like the bed of a planer, instead of vertically. The design of the

bed in any case is governed partly by the position of the spindle, and it is also affected largely by the general requirements of the work for which it is intended; for instance, milling machines which are used for milling long surfaces and for doing the same general class of work which is done on planers must have a long horizontal bed and work table, with the necessary feeding movements. Such machines are often known as the *horizontal* or *planer* type.

Milling Machines, Hand Type. The hand milling machine is so named because the table or cutter is fed by hand instead of by an automatic power feed. A typical design is so arranged that the table can be fed in a lengthwise direction by a hand lever or by turning the feedshaft with a crank. The spindle head also has a vertical lever feed. This type of milling machine is adapted to short milling operations, especially when it is desirable to take light cuts which are not of sufficient length to warrant using a milling machine having an automatic feed. When the cuts are comparatively short, the surfaces can be milled quickly and easily by using a hand-operated machine. Quite a variety of milling is done on machines of this type. For some operations, a weight is suspended at the end of the feed lever and in this way an automatic gravity feed is obtained.

Milling Machines, Lincoln Type. The well-known Lincoln type of milling machine is named after George S. Lincoln of the firm then known as George S. Lincoln & Co., Hartford, Conn. Mr. Lincoln, however, did not originate this type but he introduced an improved design. Milling machines constructed along the same general lines had previously been built by the Phoenix Iron Works of Hartford, Conn., and also by Robbins & Lawrence Co., of Windsor, Vt. Milling machines of this class are intended especially for manufacturing and are not adapted to a great variety of milling operations, but are designed for machining large numbers of duplicate parts. Some milling machines which are designed along the same lines as the Lincoln type are referred to as the *manufacturing type.* The distinguishing features of the Lincoln type are as follows: The work table, instead of being carried by an adjustable knee, is mounted on the solid bed of the machine and the outer arbor support is also attached directly to the bed. This construction gives a very rigid support both for the work and the cutter. The work is usually held in a fixture or vise attached to the table, and the milling is done as the table feeds longitudinally. The table is not adjustable vertically but the spindle head and spindles can be raised or lowered as may be required.

Milling Machines, Plain Type. This type of milling machine has a horizontal cutter spindle and is of the column-and-knee construction, which means that there is a vertical column, and a knee which is fitted to guiding ways on the face of the column, to provide vertical adjustment for the work table. The "plain" type differs from what is termed the "universal" type, in that the work table cannot be set at an angle relative to the spindle. Plain milling machines are commonly used for milling operations which can be performed by feeding the work in a straight line, either vertically or in a horizontal plane, although in modern practice there are many exceptions to this rule. In general, plain milling machines are adapted to a smaller range of work than the universal type, although many modern plain machines have attachments which greatly increase their working range. Ordinarily, plain machines are more rigid and heavier in construction than universal designs for a given size of machine, and are intended for heavier milling operations. The plain type is used principally for manufacturing operations, whereas the universal machine is intended more for tool-rooms and for a diversified line of work.

Milling Machines, Universal Type. The universal type of milling machine is so named because it is adapted to a very wide range of milling operations. The general construction is similar to that of a plain milling machine, although the universal type has certain attachments which plain machines do not ordinarily have, and which make it possible to mill a comparatively large variety of work. The universal machine has a knee which can be moved vertically on the column and a table with both cross and longitudinal movements, the same as a machine of the plain type; there is a difference, however, in the method of mounting the table on the knee. The table of a plain machine is carried by a saddle which is free to move in a crosswise direction, whereas the table's line of motion is at right angles to the spindle. The table of a universal machine also has these movements, and, in addition, it can be automatically fed at an angle to the spindle by swiveling the saddle on a lower base or "clamp-bed" which is interposed between the saddle and the knee. The circular swiveling base of the saddle has degree graduations which show the angular position of the table. This angular adjustment makes it possible to do work, such as helical milling, which could not be done on a plain machine unless a spiral milling attachment were used that provided the required angular adjustment for the cutter. Practically all universal machines are equipped with auxiliary appliances, such as the dividing or indexing head, vertical milling attachments, etc. Many of these same attachments are also used on plain milling machines which

are thus converted, to some extent, into universal types. The first universal milling machine was designed and built at the works of the J. R. Brown & Sharpe Co., in 1861-62.

Milling Screw Threads. See Thread Milling.

Mineral Black. This material is made by grinding certain kinds of slate. It is employed by the paint industry for use as a filler in the making of paints that are to be used for protecting iron and steel against corrosion.

Minerallac. Minerallac is the name of an electrial insulating compound made in different forms, either fluid, having the consistency of molasses, or semi-solid, resembling hard rubber, or as a heavy impregnating liquid. Still another form of minerallac, used as a capping compound for sealing apparatus after impregnation, is available. The softening point of semi-solid minerallac is about 120 degrees F.; the melting point, about 145 degrees F.; the flash point, 395 degrees F.; and the fire point, 425 degrees F. The dielectric strength is approximately 1000 volts per 0.001 inch.

Mineral Lard Oil. For automatic screw machine work some manufacturers use pure lard oil, but here the need of a large volume of oil causes the question of economy to play an important part; as the so-called "mineral lard oil" mixtures, ranging from 30 per cent of lard oil and 70 per cent of medium petroleum oil up to equal parts of lard oil and petroleum oil, have been found to give practically as good results as pure lard oil, it seems desirable to use these mixtures. Furthermore, mineral lard oil has an advantage over pure lard oil in that it is more fluid and thus runs more freely to the tool and work; also, this mixed oil is not so likely to give trouble from gumming.

Mineral Wool. Mineral wool is a fibrous substance made from blast-furnace slag by sending a blast of steam through the molten slag. This substance, sometimes known as "silicate of cotton," is used as a heat insulator and also as a fireproofing material. In the latter case, it is packed between the wall and floor spaces of fireproof buildings. Mineral wool may also be made by sending a blast of steam through molten rock. This "rock wool" should be used when the heat-insulating material is in contact with metal, as the sulphur in the slag wool is likely to cause corrosion. The best grades have a fine fibrous structure, and are fairly free from lumps. Variations in the character of the slag affect the grade of the wool, and there is usually a difference in the density of the wool at every cast. The method of producing mineral wool is briefly as follows: Blast-furnace slag and coke

are charged into a cupola. The molten slag, at the moment when it flows through the slag hole, is then divided into fine threads by streams of steam. These fine threads are blown into a long narrow building, where the material is stored and packed.

Miner's Inch. The term "miner's inch," used in western United States for measuring the flow of a stream of water, is more or less indefinite, because different values have been assigned to it; thus, the amount of water corresponding to a miner's inch varies from 1.36 to 1.73 cubic feet per minute, according to the method used for the measurement. The California Legislature, by an Act of 1901, prescribed that the miner's inch should be equivalent to 1.5 cubic feet of water per minute, measured through any aperture or orifice. The most common measurement is through an aperture 2 inches high and through a plank 1¼ inches thick, the width of the aperture being whatever length is required. The lower edge of the aperture is placed 2 inches above the bottom of the measuring box and the plank is 5 inches high above the aperture, so that the head will be 6 inches above the center of the stream through the orifice. Each square inch of the opening represents a miner's inch, and the amount of water that will flow through it equals about 1½ cubic feet per minute.

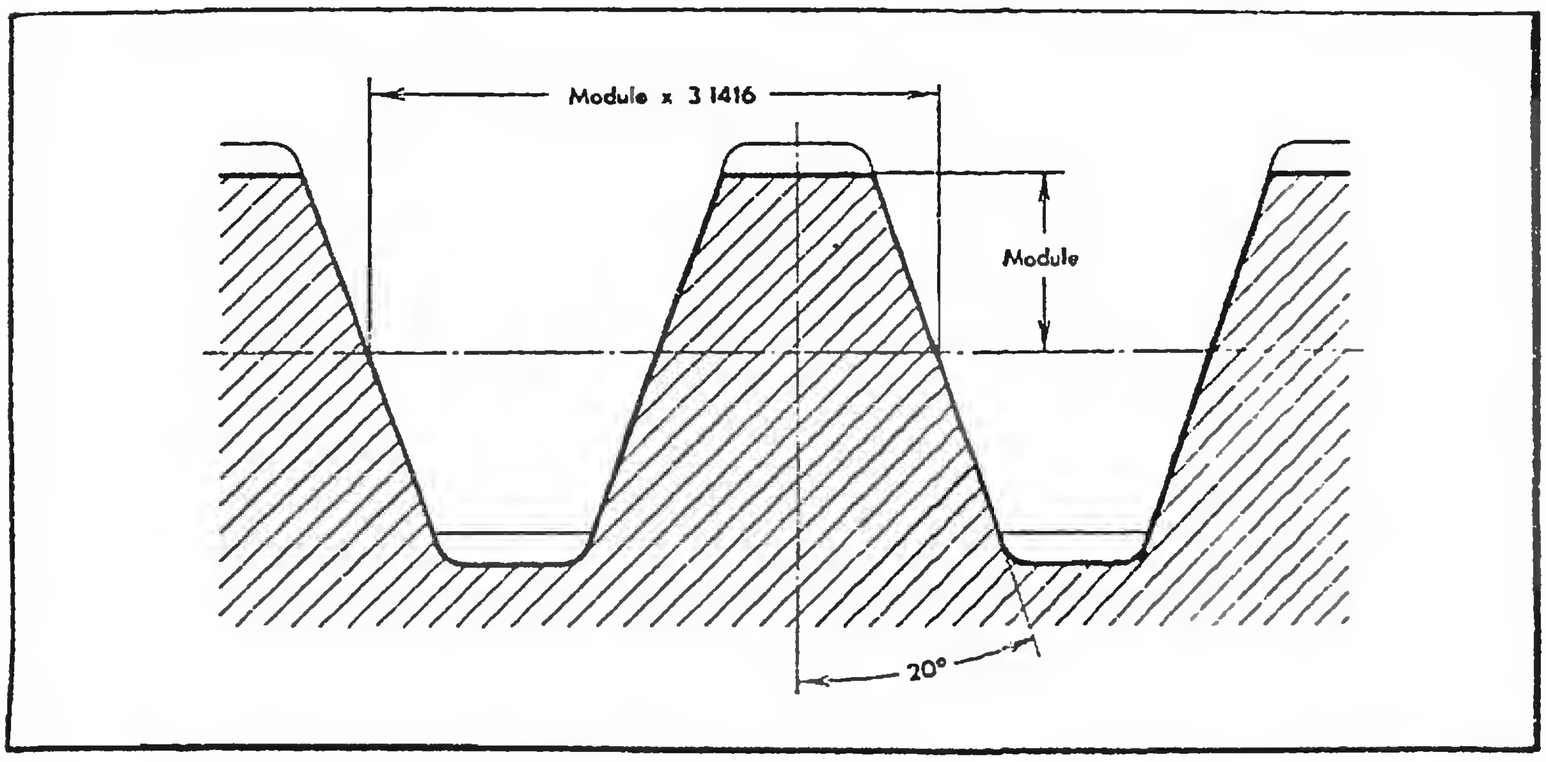
Minofor Metal. Minofor metal is a tin-antimony-copper alloy containing a large percentage of zinc. It belongs to the britannia metal class, and contains, on an average, 68.5 per cent of tin, 18.2 per cent of antimony, 3.3 per cent of copper, and 10 per cent of zinc.

Minor Diameter. The smallest diameter of the thread on the screw or nut is the "minor diameter." This term has been used to replace the term "core diameter" as applied to the thread of a screw and also the term "inside diameter" as applied to the thread of a nut. See also Major Diameter.

Miter Gears. If the number of teeth in two bevel gears is alike, the gears are equal, the pitch-cone angle of each being 45 degrees, and the gears are commonly referred to as miter gears. All dimensions in the two gears are the same, and the gears are interchangeable.

Module System for Gear Teeth. The *module* of a gear equals the pitch diameter divided by the number of teeth, whereas *diametral pitch* equals the number of teeth divided by the pitch diameter. The module system is in general use in countries which have adopted the metric system; hence the term module is usually understood to mean the pitch diameter *in millimeters* divided by the number of teeth. The module system may, however, also

be based upon inch measurements and then it is known as English module to avoid confusion with the metric module. Module is an actual dimension, whereas diametral pitch is only a ratio. Thus, if the pitch diameter of a gear is 50 millimeters and the number of teeth 25, the module is 2, which means that there are 2 millimeters of pitch diameter for each tooth.



Basic Rack of German Standard Tooth Form for Spur and Bevel Gears

German Standard: The illustration shows the basic rack of the German Standard (DIN — 867). The flanks or sides are straight (involute system) and the pressure angle is 20 degrees. The shape of the root clearance space and the amount of clearance depend upon the method of cutting and special requirements. The amount of clearance may vary from 0.1 $\times$ module to 0.3 $\times$ module. It is the common practice among American cutter manufacturers to make the clearance of metric or module cutters equal to 0.157 $\times$ module.

Modulus of Elasticity. When a structural material such as steel, for example is subjected to a load, there is a certain amount of deformation or change in form due to the elasticity of the material. When a load is applied, there is an internal resisting force or reaction called a *stress,* and the amount of deformation due to the load is called a *strain.* The ratio of unit stress to unit strain is known as the *modulus of elasticity,* and this may be used for determining the strain or deformation resulting from a given load. If the stress in pounds per square inch is divided by the strain or deformation in 1 inch caused by this stress, the ratio thus obtained will equal the modulus of elasticity for that ma-

terial. This modulus is generally denoted by E. If an elongation of 0.030 inch is produced in an alloy steel bar, 10 inches long, by a load of 90,000 pounds per each square inch of cross-section of the bar, then the modulus of elasticity is:

$$E = \frac{90{,}000}{0.030 \div 10} = 30{,}000{,}000.$$

The elongation is assumed to be proportional to the load up to the elastic limit; hence, the modulus of elasticity of a material may be used for finding the elongation e produced by any load per square inch, S, by the formula: $e = S \div E$.

The modulus of elasticity for steel is usually 29,000,000 to 30,000,000. While steels vary greatly in regard to tensile strength, the modulus of elasticity is about the same in all cases. Since modulus of elasticity is an indication of stiffness or rigidity, it is evident that the strength of steel is not a measure of rigidity. In other words, a part made of low-carbon steel having an ultimate strength of, say, 60,000 pounds per square inch, may be just as rigid as a part made of alloy steel and having double this strength, assuming that the stresses in both cases are below the elastic limit of the material. The modulus of elasticity in tension and in compression is practically the same for most metals. The term "modulus of elasticity" is generally understood to mean the tension modulus.

Modulus of Elasticity in Shear: The modulus of elasticity in shear, or shear modulus, is also known as the modulus of rigidity and as the modulus of transverse elasticity. The shear modulus (G) is about 0.40 times the modulus of elasticity (E) in tension or $G = \dfrac{E}{2\,(1 + m)}$ in which m equals Poisson's Ratio.

Modulus, Section. See Section Modulus.

Mohs's Hardness Scale. Hardness, in general, is determined by what is known as Mohs's scale, a standard for hardness which is mainly applied to non-metallic elements and minerals. In this hardness scale there are ten degrees or steps, each designated by a mineral, the difference in hardness of the different steps being determined by the fact that any member in the series will scratch any of the preceding members. This scale, which was devised in 1820 by F. Mohs, for the purpose of expressing the hardness of minerals by numbers, is as follows:

1. Talc; 2. gypsum; 3. calcite; 4. fluor spar; 5. apatite; 6. orthoclase; 7. quartz; 8. topaz; 9. sapphire or corundum; 10. diamond.

These minerals, arbitrarily selected as standards, are successively harder, from talc, the softest of all minerals, to diamond, the hardest. This scale, which is now universally used for non-

metallic minerals, is, however, not applied to metals as entirely different and more precise methods are employed.

Moisture in Compressed Air. See Compressed Air, Moisture in.

Moisture in Lumber. See Lumber Water Content.

Mol. The term "mol" is used as a designation of quantity in electro-chemistry, and indicates the number of grams of a substance equal to its molecular weight. For example, one mol of sillver-nitrate equals 169.89 grams, the molecular weight of silver-nitrate being 169.89.

Molding. Molding is a process by which an impression or mold is formed in damp sand or other plastic material in such a way that it can be used as a form into which molten metal is poured to produce a casting corresponding to the shape of the impression or mold. Ordinarily a pattern is used to form the mold, and when the pattern is removed it leaves a cavity of the required shape, into which molten metal is poured. The sand or other material for making molds for small and medium-sized castings is usually confined in molding boxes called flasks, while the molds for large pieces are made directly on the foundry floor which is provided with pits filled with molding sand to a depth of several feet.

Green Sand Molding: The green sand method of making molds is the most important branch of the molder's work, as the majority of castings are made by this method. The term "green sand" means that the mold is used at once or while in a green or damp condition. The interior surfaces of the mold are "skin-dried" in some cases.

Dry Sand Molding: This branch of molding differs from green sand molding in that molds, after being made from damp sand, are dried or baked in an oven or by special apparatus, to make the body of the mold comparatively hard and firm. This method is used for the more intricate castings or when a fine surface is desired. The dry condition of these molds permits a higher degree of surface finishing, and, owing to the absence of moisture, but little gas is generated, and this finds easy exit through the dry sand.

Loam Molding: When castings are made in molds that are composed of brickwork and loam, the process is termed *loam molding.* The loam used for the inner surface or face of the mold is a natural mixture of loam and clay, and the brickwork forming the outer support is laid up in courses to conform approximately to the shape required for the mold. Loam molds can be made by the use of spindle and sweep, strickle, or pattern; many loam molds require the use of all three means. Cylindrical molds are

usually formed by spindle and sweep, while patterns are used to form branches, hubs, etc., that are fitted to the outside. This is the most expensive method of molding, but in many cases the cost of a large portion of the pattern work is eliminated, and for many jobs it is the most economical.

See also Shell Molding.

Molding Machines. Molding machines are extensively used in modern foundries, especially where duplicate castings are required in large numbers. The function of these machines varies with different types. Some molding machines are designed for ramming or packing the sand in the molds, whereas other types are intended primarily for turning or rolling over the flask or mold, and withdrawing the pattern after ramming. Molding machines were designed originally for withdrawing the pattern from the sand by a steady mechanical action, in order to avoid breaking away parts of the mold, which often occurs when a pattern is removed by hand. Withdrawing the pattern is still the most important function of certain types of molding machines, but many of the designs now in use are also arranged for ramming or packing the sand by mechanical means. There are three general classes of molding machines: (1) Those that withdraw the pattern after the mold has been rammed by hand; (2) those that ram or pack the sand into the mold, but are not designed to withdraw the pattern; and (3) those that serve both to ram or pack the sand and withdraw the pattern from the mold. These three classes include many designs and types that differ in regard to the source of power for operating them and the mechanical action either for packing the sand or for withdrawing the pattern. For instance, some machines, especially those used for small work, are manually operated, whereas others are actuated either partially or entirely by power. There are several methods of packing or ramming sand around patterns in molds. The terms applied to the different methods indicate the general nature of the ramming operation; thus, there is the "jarring" or "jolting" method, the "squeezing" or "pressing" method, the "gravity" method, and the "roller" method.

Molding Machines, Gear. There are two general methods of making cast gears. One is to use a pattern which is a duplicate of the gear required, and the other is to form a mold by using a special machine designed for this purpose. Patterns are liable to warp and twist out of shape and it is difficult for a patternmaker to make all of the teeth uniform in size, shape, and pitch. These patterns are also expensive to construct. When a molding machine of the ordinary type is used, the molding is done either by a single tooth or a segment containing two or three teeth. This segment is located at the required radial posi-

tion and the impressions or teeth are formed in the side of the mold progressively, by indexing either the arm which carries the tooth segments or the mold itself.

Floor Type of Gear Molding Machine: There are two general classes of machines for molding gears which are the *floor* and *table* types, respectively. The floor type has a vertical column carrying a horizontal slide to the end of which a vertical arm is attached. A hard-wood gear-tooth segment is attached to the end of this vertical arm which is adjusted to the required radius by the horizontal slide. The tooth impressions in the mold are rammed up one or two at a time, and the segment block is indexed around the mold in accordance with the circular pitch of the gear teeth, by means of an indexing mechanism forming part of the machine. Some machines of this type have a worm-wheel and worm which are rotated through change-gears selected to give the required indexing movement. Another method of indexing is by means of a cylindrical drum attached to the top of the vertical column and provided with annular rows of accurately-spaced holes which vary in number. In order to control the indexing movement, these holes are engaged by a plunger carried by an arm that is connected with the horizontal arm of the machine.

Table Type of Gear Molding Machine: With the table type of gear molding machine, the flask for the mold is mounted upon a table which is given the necessary indexing movement. One design is quite similar in appearance to a large vertical boring mill. There is a circular table upon which the mold is mounted and two housings which support a cross-rail. This cross-rail carries a vertical slide to the lower end of which a one-tooth pattern block is attached. This pattern block is made of hard wood, and, when molding a gear, no draft whatever is required, because the block is removed from the mold horizontally. The table of the machine is equipped with an indexing mechanism of the change-gear and worm-wheel type. While these molding machines produce very accurate gear molds, the finished cast gear is liable to be somewhat out of round, owing to uneven shrinkage of the arms. These defects, however, may be so slight as not to affect the use of the gears for many purposes, but, when greater accuracy is desired, the rim is cast separately and is fastened to a gear center or spider. These machine-molded gears can be strengthened, if necessary, by shrouding the teeth, and they possess considerable surface hardness due to the quick cooling of the casting in the mold. Very large cast gears are produced in this way and give good results for many purposes, especially when the peripheral speeds are low and a slight amount of backlash is not objectionable. When molding a spur gear on this machine, the ring of sand inside of the cast-iron flask is first formed by means of

a sweep. It is also necessary to provide a core-box for forming the arms of the gear. Geared-tooth molding machines have been applied to the molding of spur gears, bevel gears, helical gears, and worm gears.

Molding Sand. Molding sands, which are used in the foundry for the making of molds for castings, are of two classes: (1) "Facing sand," which comes into actual contact with the pattern, and (2) "floor" or "black sand" which is used as a support for the facing sand, and fills up the remainder of the molding box or flask. The floor or black sand is the sand that has already been used as a facing sand. Molding sand is practically a mixture composed of silica and clay, with various proportions of lime, magnesia, iron oxide, organic matter, and water, the essential qualities being porosity, plasticity, and refractoriness. The amount of silica determines, to a large extent, the last of these qualities. The shape and size of the grains of silica and the quality of the clay bond also have an effect upon the heat-resisting qualities of the sand. The less iron, lime, and magnesia the sand contains, the better it is suited for molding purposes, because these substances combined with the silica form the more or less fusible slags called "silicates." The higher the melting point of the metal to be cast, the more refractory should be the sand from which the molds are made. A very refractory sand is required for nickel, which melts at a temperature of 2650 degrees F., and also for steel, which fuses at about the same heat. There are few natural sands that will withstand a temperature of 2500 degrees F. without fusing; therefore, in casting steel, the molds are invariably faced with a very refractory facing of pure silica bonded with fireclay, as ordinary molding sand would produce a pitted surface on the casting.

Molds, Metal. Metal "long-life" or permanent molds, for casting molten metal of comparatively high melting temperature, are designed so that a mold may be used continuously, replacing sand molds which are destroyed after being used once. More than 40,000 castings have been made from a single metal mold. Iron, unless of very high silicon content, if poured into a chilled mold, will be hard and white, but a process developed for casting iron in metal molds provides a heat barrier between the mold and the casting. The mold is thinly covered with a coating which checks the heat flow sufficiently to prevent the formation of chilled iron. This coating is further protected by a thick coating of lampblack, and the carbon, uniting with the skin of the casting, lowers its melting point, and thereby retards the cooling rate of the casting. This process of molding is applicable to the largest as well as to the smallest type of casting. Aluminum and brass have also been poured in these molds. See Casting in Permanent Molds.

Molds, Plaster. See Plaster Molds.

Molds, Water-Cooled In brass foundries, cast-iron chilled molds have long been used for casting the plates used in producing sheet brass by the rolling process. In many foundries, especially in Europe, chilled molds of the water-cooled type are being used. A relatively thin metal wall is in contact with the molten metal on one side and with cooling water on the other. Such molds may be used continuously, castings being made every five or ten minutes, whereas with the older cast-iron chill type a comparatively large stock of molds is required to allow sufficient time for cooling before making another casting. With the water-cooled mold the rate of cooling may be varied by regulating the water supply. These water-cooled molds have proved very durable. Plates cast in them are said to be improved in their physical structure and less liable to impair the quality of the rolled sheets as the result of surface cracks and blistering of the castings.

Molecular Weight. The smallest mass of a chemical combination which can be conceived of as existing and yet preserving its chemical properties is known as a *molecule.* The molecular weight of a chemical compound is equal to the sum of the atomic weights of the atoms contained in the molecule, and are calculated from the atomic weights, when the symbol of the compound is known. The atomic weight of silver is 107.88; of nitrogen, 14.01; and of oxygen, 16; hence, the molecular weight of silver-nitrate, the chemical formula of which is $AgNO_3$, equals $107.88 + 14.01 + (3 \times 16) = 169.89$.

Molten-Metal Explosions. Accidents which occur in foundries are often due mainly to the handling of molten metal. With proper precautions, a number of these accidents could be reduced. Molten metal will produce serious explosions when it comes in contact with damp ground, or with any cold, damp surface. Ladles should be free from moisture before metal is poured into them, and molds should be dry. Ladles should always be heated before pouring metal into them. In foundries making small castings, double-handled ladles holding about 100 pounds of metal, or single-handled ladles holding from 25 to 40 pounds, are employed. The greatest number of accidents due to burns, in proportion to the number of men employed, occur in foundries where hand ladles are used. Many are caused by the metal splashing from the ladles as it is poured from the cupola spout. Dangers of this kind may be eliminated by placing the hand ladle inside of a larger stationary ladle, located so that it will catch the splash. A stand may also be used on which the handle ladle rests while the metal is poured, so that the workmen may step back, out of range of the splash.

Molybdenum. Molybdenum is one of the metallic chemical elements, the symbol of which is Mo, and the atomic weight, 96. The metal is related to chromium, tungsten, and uranium, and is obtained in the form of a powder of gray color. Pure molybdenum, in its powder form, has a specific gravity of 9.01. It is malleable, but of great hardness, although not so hard as glass. Molybdenum is found in nature chiefly in the mineral molybdenite, and is also present in many iron ores. It is used in the making of alloy steels, chemical reagents, dyes, glazes and molybdenum disulphide, a dry film lubricant (See Lubrication with Metals and Metal Compounds).

Molybdenum Steel. Molybdenum steels have properties similar to tungsten steels, except that a smaller quantity of molybdenum than of tungsten is required to secure the same results; hence, the main use of molybdenum is in the manufacture of high-speed steel. Molybdenum increases the elongation of steel considerably; hence, it is also used in steel which is to be manufactured into wire, because the increase of elongation necessary for wire drawing can be obtained at a comparatively small cost. A molybdenum steel for structural purposes is also made by adding a molybdenum-nickel alloy to steel. This alloy contains about 75 per cent of molybdenum and 25 per cent of nickel, or about 50 per cent of molybdenum and 50 per cent of nickel. Besides these constituents, the alloy contains small percentages of iron, carbon, and silicon, usually from 2 to 2.5 per cent of iron, from 1 to 1.5 per cent of carbon, and from 0.25 to 0.50 per cent of silicon. The molybdenum steel made by an addition of these alloys is adapted for large crankshafts and propeller shafts, for large guns, rifle barrels, and boiler plates.

The S.A.E. molybdenum steels have carbon ranging from 0.17 to 0.67, manganese ranging from 0.40 to 1.00, chromium ranging from 0.40 to 1.10, and molybdenum ranging from 0.15 to 0.30.

Mo-Max. A steel containing 8 per cent molybdenum, 2 per cent tungsten, 4 per cent chromium, and 1 per cent vanadium. Comparable to high-tungsten steel without containing a high percentage of tungsten. Tools made from Mo-Max generally have greater hardness than those made from 18-4-1 high-speed steel, and equal or greater toughness. Can be used for all types of tools for which regular tungsten high-speed steel is used; presents special advantages in machining work where difficulties have been encountered in using regular high-speed steel tools.

Moment of a Force. The action of a force upon a lever causes a tendency on the part of the lever to turn about its fulcrum. The magnitude of this tendency depends, first, upon

the magnitude of the force acting, and, second, upon the perpendicular distance from the line of action of the force to the fulcrum. If the force is increased, or its perpendicular distance from the fulcrum is made greater, the tendency to turn the lever about its fulcrum will increase. This rotating effect of a force about a fulcrum is termed the "moment of the force" and is equal to the product obtained by multiplying the force by the perpendicular distance from the fulcrum. If the force is measured in pounds and the distance in feet, the moment is measured in foot-pounds or preferably as pound-feet (see Pound-foot), if the force is measured in pounds and the distance in inches, the moment is measured in inch-pounds or pound-inches. The most important principle to be observed with regard to moments is that the distance from the fulcrum to the force, generally called the "lever arm," must be measured on a line at right angles to the direction of the force.

Moment of Inertia. The moment of inertia of a body, with respect to an axis, is the sum of the products obtained by multiplying the mass of each elementary particle by the square of its distance from the axis; hence, the moment of inertia of the same body varies according to the position of the axis. It has its minimum value when the axis passes through the center of gravity. The moment of inertia is numerically equal to the mass of a body which, if it could be conceived of as concentrated at a distance of unity from the axis of rotation, would, if actuated by the same forces, rotate with the same angular velocity as that of the actual body. In other words, the moment of inertia bears the same relation to angular acceleration as mass does to linear acceleration. When the term "moment of inertia" is used in regard to areas, it is equal to the sum of the products obtained by multiplying each elementary area by the square of its distance from the axis. The moments of inertia of surfaces are especially useful in calculating the strength of beams.

Momentum. The momentum of a moving body is the intensity of that constant force which, resisting its movement, would bring it to rest in one second; hence, the momentum is equal to the mass multiplied by the velocity in feet per second, or:

$$\text{Momentum} = \frac{\text{weight}}{32.16} \times \text{velocity in feet per second.}$$

Monel Metal. Monel is a nickel-copper alloy that is extensively used especially where a combination of high strength, toughness and corrosion resistance are essential. There are various grades or types of Monel, depending upon the application and

properties required. The nickel content varies from 65 to 67; copper, 29 to 30; iron, 0.9 to 1.5; silicon, 0.25 to 3; manganese, 0.3 to 1; carbon, 0.15 to 0.2 per cent. The composition known as *K*-Monel is practically the same as the other grades excepting that it contains about 2.75 per cent aluminum. *K*-Monel is ordinarily used when, in addition to high corrosion resistance, it is essential to have higher hardness and even greater strength than obtainable with the other alloys.

As Monel metal possesses excellent resistance to corrosion either by natural waters (hard and soft) or salt water, it has been widely used for parts of water meters, pumps, propeller shafts, propellers, pump shafts and pump impellers, condenser tubes and bolts, domestic hot-water storage tanks and heaters, etc. Monel offers good resistance to corrosion by all acids except those of a highly oxidizing character. It also offers useful resistance to corrosion by all the common organic acids and is practically free from corrosion by neutral and alkaline organic compounds. Monel is practically completely resistant to most alkaline solutions. The tensile strength of cold-drawn rods may vary from 85,000 to 125,000 pounds per square inch.

Monitor Lathes. Turret lathes which are intended principally for brass work are often referred to as *monitor lathes*, the name "monitor" in this connection indicating a revolving turret. This name is not applied to the same design of turret lathe by different manufacturers, although, in general, it indicates a comparatively small turret lathe which, in many cases, is provided with a thread-chasing attachment of the Fox lathe type and is designed principally for turning, boring, and threading parts made of brass. Some lathes which are listed as the monitor type have a stock-feeding mechanism, whereas others do not have this feature. The turret may or may not have power feed, and some monitor lathes have a cross-feed for the turret, whereas others only have the longitudinal feeding movement. The thread-chasing attachment is one of the important features of the monitor or Fox lathe, as it enables parts to be threaded rapidly, and is used on many classes of work in preference to a die held in the turret.

Monovalent. Monovalent, also known as univalent, is a term used to designate that an atom of an element (like hydrogen) combines with but one atom of another element.

Moore & Beeman Rule. This is a rule employed for finding the board measure of logs, as follows: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply the result by the length of the log in feet. Usually the diameter is measured inside of the bark at the small end.

Morse Taper. Dimensions relating to Morse standard taper shanks and sockets may be found in tabular form in engineering handbooks. The taper for different numbers of Morse tapers is slightly different, but is approximately $\frac{5}{8}$ inch per foot. The figures accurate to four decimal places are as follows: No. 0 taper, 0.6246 inch per foot; No. 1, 0.5986; No. 2, 0.5994; No. 3, 0.6023; No. 4, 0.6233; No. 5, 0.6315; No. 6, 0.6256; No. 7, 0.6240. Morse taper shanks are used on a variety of tools and exclusively on twist drills.

Mortise-and-Tenon. The joining of two pieces of wood by what is termed a mortise-and-tenon joint is effected by first cutting a rectangular hole or slot (called the mortise) in one member. The end of the other member is then cut to form the tenon which fits into the mortise. The mortise-and-tenon joint may be either "through" or "blind." If through, the tenon fits a mortise cut completely through the first member; if blind, the tenon fits a mortise cut part way through. In joining two pieces of equal thicknesses, with this type of joint, the mortise-and-tenon are generally cut symmetrically so that when the two members are put together their sides will be in the same plane.

Motor, Electric. A motor is a machine for transforming electrical energy into mechanical energy. It usually consists of a stationary element called a stator or field which is made up of two or more electromagnetic poles fastened equidistantly around the inside periphery of an iron frame and a rotating element mounted on a shaft called a rotor, or armature, which usually consists of a steel or iron core supporting a number of parallel conductors in the form of bars, straps, or coils. One variation from this usual construction is the alternating-current synchronous motor wherein the pole pieces are attached to the rotor, in this case called the field, and the parallel conductors are fastened around the inside periphery of the stator, called the armature.

Rotation in a motor is produced by an interaction between electric current in the armature conductors and the interlinking magnetic flux produced by the field poles. This rotation is explained by the well-known principle that when a conductor carrying an electric current is placed in a magnetic field, the conductor will tend to move, the direction of motion depending upon the direction of the current in the conductor and the direction of the flux in the magnetic field.

When current is supplied to the armature or rotor windings (i.e., where it is not set up by induction from the field windings as in a squirrel-cage induction motor) it passes through brushes which bear upon either a set of slip rings or a commutator. The commutator is used where direct current must be converted into alternating current in the armature windings.

By varying the number, distribution, and type of conductors in the armature and by changing the electromagnetic field arrangement and energizing electric circuit, motors of widely different characteristics may be designed for practically any type of application where mechanical power is needed and electrical energy is available. See Motor Selection, Alternating Current and Motor Selection, Direct Current.

Alternating-current motors are designed to operate on alternating-current circuits, although some types, such as the widely used universal series-wound fractional horsepower motors, may also be operated by direct current. Alternating-current motors may be grouped into three classes: (1) Synchronous motors, (2) polyphase induction motors, and (3) single-phase motors.

1. Synchronous motors are so called because they operate at synchronous speeds determined by the frequency of the current and the number of poles for which they are wound. See also Synchronous Motors.

2. Polyphase induction motors might be considered as essentially transformers with a secondary which is free to move or rotate. There are two main types: The squirrel-cage induction motor has for rotor or secondary conductors simply a set of bars which are laid in slots around the rotor and which are connected at each end by a continuous ring, thus virtually forming a "squirrel cage" from which the motor takes its name. This squirrel cage is not electrically connected to the power supply, and the only currents which flow in it are those which result from the electromotive forces induced by the alternating flux of the stator field; hence, the term *induction motor*. The wound-rotor induction motor has, in addition to a squirrel cage, a series of wire-wound coils which constitute an auxiliary winding, and these are connected to collector rings. Thus, an external resistance may be connected in series with it for control purposes. See also Induction Motors, Polyphase.

3. Single-phase motors find especially wide usage in the small fractional horsepower sizes. There are several types, among which may be mentioned the repulsion type with a winding on the rotor which is connected to a commutator to aid in starting and which may also have a squirrel-cage winding for running; the split-phase type which has two windings on the stator, only one of which is used for running, the other being provided in combination with the first to afford starting torque; the capacitor type which is really a modification of the split-phase motor by the addition of a fixed capacitor which may aid in starting and running characteristics; the series-wound universal motor which is similar in construction to a direct-current series motor, except that it has a laminated stator frame; and the adjustable-speed,

brush-shifting motor which is of the repulsion type with a provision for speed control by shifting of the brushes. See also Single-Phase Motors.

Direct-current motors may be grouped into three main classes: (1) Series-wound motors, (2) shunt-wound motors, and (3) compound-wound motors.

1. The series-wound motor has its field windings in series with the armature. It is essentially a variable-speed motor, the torque of which increases with the load. A variation of this type, called the series shunt-wound motor, has a light shunt winding in addition to the series winding to prevent excessive speed at light load. See also Series-Wound Motor.

2. The shunt-wound motor has its field in parallel with the armature providing practically constant excitation, and constant speed and torque. Speed control may be effected by the introduction of a variable resistance into the armature or field circuits or by some form of voltage control. See also Shunt-Wound Motor.

3. The compound-wound motor has both series and shunt windings in the field and partakes of the characteristics of both of these other types of motors in varying degrees, depending upon the relative strengths of its two fields. See also Compound-Wound Motor.

Motor Converter. According to the American Standard, a motor converter consists of an induction motor and a synchronous converter with their rotors mounted on the same shaft and with their rotor windings connected in series. Such a converter operates synchronously at a speed corresponding to the sum of the numbers of poles of the two machines. Voltage control with a motor converter is obtained by the same methods as are used with a synchronous converter.

Motor-Generator Sets. According to the American Standard a motor-generator set is a machine which consists of one or more motors mechanically coupled to one or more generators. They are usually mounted on the same base and may have a common shaft and bearings. For convenience, motor-generator sets may be divided into three general classes, as follows: (1) Direct current to direct current, including boosters and balancers; (2) Alternating current to direct current, or vice versa, including light, power and railway service; (3) Alternating current to alternating current, as in the case of frequency changers.

Motor History. The origin of the electric motor may be traced back to the experiments of Faraday in 1821. These experiments were followed by crude forms of magnetic apparatus which had moving elements. In 1826, 1830 and 1831 crude magnetic devices containing moving elements were made, and in 1832 and 1834

rotary motors were constructed which had electromagnets both in the field and armature. All of these primitive designs were operated by batteries and the practical development of the motor did not begin until the dynamo was invented. The structural relationship between the dynamo and motor was discovered accidentally in 1873, due to the fact that one dynamo was inadvertently connected to another in active operation. When it was found that the dynamo revolved as the result of this connection to the other machine, the subsequent development and wide application of the electric motor was assured. This discovery was made at an industrial exhibition in Vienna.

Motor Rotation Direction. According to the adopted standard of the National Electrical Manufacturers Association, the standard direction of rotation for all non-reversing direct-current motors, all alternating-current single-phase motors, all synchronous motors, and all universal motors, is *counter-clockwise* when facing that end of the motor opposite the drive.

This rule does not apply to two- and three-phase induction motors, as most applications on which they are used are of such a nature that either or both directions of rotation may be required, and the phase sequence of the power lines is rarely known.

Motors, Control Equipment. The control of electric motors involves the use of suitable auxiliary equipment for their manual or automatic starting, stopping, reversing, or speed variation. In some cases, control equipment is designed as an integral unit to perform all these functions, but more often it is limited to a starting and stopping function.

Starting and Stopping: Many types of small motors, such as those in the fractional horsepower range, can be connected directly to the line for starting. For these, a relatively simple device in the form of an enclosed push-button, toggle or knife switch is used.

Larger motors, however, draw a heavy current on starting and it is customary to insert a resistance in either stator or rotor windings, according to the type of motor, and to cut out this resistance either in a series of steps or in one operation when the motor reaches some predetermined speed or speeds. For manual step-by-step control, some form of rotary switch which has one or more arms bearing on contacts in the form of a dial or a drum may be used, or a series of single-pole switches may be closed in sequence. The same result is obtained automatically by using a series of relays which, after starting by push-button or some other form of remote control, may be governed in their sequential operation by some form of timing device, or by the actual flow of current being controlled.

Reduced voltage starting is used for synchronous and induction motors, and for this purpose an auto-transformer is often utilized. In starting, connection is made to a tap on the transformer which provides current at reduced voltage; and when the proper motor speed has been reached, the full-line voltage is applied. A reactance coil or resistance of suitable design serves the same purpose. Thus, in the case of squirrel-cage induction motors, a resistance is placed in series with each phase during starting when the control is moved to the "start" position. At the proper motor speed, the control is shifted to the "run" position and the entire resistance is cut out. Synchronous motors require additional equipment to effect the changeover or connection to synchronous windings when synchronous speed has been nearly attained.

Speed Control: For those motors in which the speed of rotation can be adjusted — chiefly series-wound, shunt-wound, and compound-wound direct-current motors, and series-wound universal motors—a variable-resistance control is provided. In the case of shunt-wound motors, the resistance may be placed either in series with the armature, where it will serve to provide lower motor speeds, or in series with the field, where it will serve to provide higher motor speeds, or in both to effect a wide range of speed variation. In the case of series and universal series-wound motors, the resistance is inserted in series with the armature and the field.

For shunt-wound motors another means of speed control is to vary the voltage applied to the armature. A separate direct-current generator is provided for this purpose and its armature is connected in series with the motor armature. Speed control is effected over a range as great as 12 to 1 by adjustment of the generator field strength with a rheostat.

The speed of induction motors may be changed by varying the voltage applied to the primary or, in the case of the wound rotor type, by inserting a resistance in series with the special winding in the secondary.

The speed control may be a separate device from the starter or it may be an integral part of it but having an additional set of contacts for the variation of the separate resistance forming the speed control. The basic difference between a starting resistance and a speed-controlling resistance is in the design of the latter to remain in constant operation without overheating.

Multi-speed motors, which operate at a number of different fixed speeds, are of the squirrel-cage, wound-rotor or synchronous type and have either two or more windings, each of which provides a different number of effective magnetic poles due to their spatial arrangement around the stator, or a single winding, part

of which may be cut out to reduce the number of poles to one-half, or a combination of these two arrangements. The change in connection from one winding to another is usually effected by some form of drum controller.

Mechanical control of motor speed is accomplished in the case of a brush-shifting, adjustable-speed motor by a lever which moves the position of the brushes on the commutator. Variable-speed transmissions which may or may not be integral with the motor are also used to secure a wide range of speeds.

Motor Selection. The first step taken in selecting a motor for a specific drive is an analysis of the machine to be driven. During this analysis, such questions are answered as: What horsepower is required to drive the machine? Will the power demand be greatest for starting, running, or acceleration? What is the expected duration of the peak load? Is a constant or a varying torque needed? Will a single constant speed be all that is required or will several fixed speeds be needed at various times? If a variable speed is needed, over how wide a range will it extend? What are the possible deleterious conditions to which the motor may be subjected?

Then comes the task of selecting a motor to fit these requirements as closely as possible. A standard type of motor is desirable and one that is quite close in capacity to the normal load demand. It is no longer considered to be good practice to install motors with capacities greatly in excess of that normally called for by the machine which they are to drive. One reason is that many types of motors operate at lower efficiencies, and in the case of alternating-current types at lower power factors, when running on partial loads. Also to be considered is the possibility that overpowering may result in damage to the machine to which the motor is connected, should interference in machine operation be experienced while the motor is driving. One exception to overpowering, however, may be made in the case of the synchronous motor. When a motor of this type which is larger than needed is installed, the excess magnetizing current may be useful in improving the power factor of the plant in which it is installed.

Speed: From the standpoint of speed, the motor selected may be of the varying-speed type which varies with the load; an adjustable-speed type which can be controlled over a given range with a reasonable degree of stability; an adjustable varying-speed type which can be adjusted to certain speeds but which will, nevertheless, vary from these speeds as the load changes; a multi-speed type which provides a choice of two, three, or four fixed speeds; or a constant-speed type which will have very little, if any, speed variation.

Load: From the standpoint of the load, the motor selected

may have to deliver practically constant horsepower at varying speeds, in which case the torque will vary inversely as to speed; practically constant torque with varying speeds, in which case the horsepower will vary directly as to speed; or variable torque in which both horsepower and torque vary with the speed.

In selecting motors for various applications, the following general rules may serve as a guide:

For adjustable- or variable-speed control, use (1) direct-current motors; (2) wound-rotor induction motors; or (3) multi-speed alternating-current motors.

For high starting torque, use (1) cumulative compound-wound or series-wound direct-current motors; (2) wound-rotor induction motors; (3) high torque squirrel-cage motors; (4) repulsion-induction single-phase motors; or (5) special capacitor motors.

For a relatively constant speed with variations in the load, use (1) shunt-wound direct-current motors; (2) general-purpose squirrel-cage motors; or (3) repulsion-induction and split-phase single-phase motors.

For very high speeds, use (1) universal motors; or (2) high-frequency squirrel-cage motors.

Protective Enclosures: To meet the various kinds of conditions imposed by different locations, the following types of motor enclosures are provided: Semi-enclosed, usually for mechanical protection only; totally enclosed, for added protection against dirt, dust, or lint; totally enclosed fan-cooled, which not only afford protection against dirt, dust or lint, but also provide greater air circulation and higher heat-radiating capacity; splash-proof, for added protection against liquids splashed or dripped on them; ventilated, to provide fresh air circulation through the windings, where the surrounding atmosphere is unstable for ventilation; and explosion-proof, for protection against explosion from combustible vapors rising from gasoline, naphtha, petroleum, benzol, alcohols, acetone, lacquer solvents, and natural gas.

Hazardous Conditions: Extreme care should be used in the proper selection of apparatus in order that successful operation and good service will result. Where the apparatus is subjected to unusual risk, the manufacturer should be consulted; especially where the apparatus is used under the following conditions: (1) Exposed to chemical fumes; (2) operated in damp places; (3) operated at speeds in excess of over-speed limitations specified; (4) exposed to combustible or explosive dust; (5) exposed to gritty or conducting dust; (6) exposed to lint; (7) exposed to steam; (8) operated in poorly ventilated rooms; (9) operated in pits, or where entirely inclosed in boxes; (10) exposed to inflammable or explosive gases; (11) exposed to temperatures below 10 degrees C.; (12) exposed to oil vapor; (13) exposed to salt

air; (14) exposed to abnormal shock or vibration from external sources; (15) where the departure from rated voltage is excessive; (16) where the alternating supply voltage is unbalanced.

Motor Selection, Alternating Current. For alternating-current operation, the following general types of motors are available:

Squirrel-cage motors which are characterized by practically constant speed dependent upon the frequency. There are six main types:

1. Normal starting torque—normal starting current type which has a starting torque of about 150 per cent of full load torque in the case of two- and four-pole motors, but which requires a high starting current.
2. Normal starting torque—low starting current type which is so designed as to require a relatively small starting current.
3. High starting torque—low starting current type which has added starting torque due to the provision of a special winding of high resistance and low reactance.
4. High starting torque—medium starting current—high slip type which provides for a higher amount of slip in case of overload than is customary in general-purpose motors and is similar in operating characteristics to the compound direct-current motor.
5. Low starting torque—normal starting current type which has a large initial current requirement for starting but rather low torque.
6. Low starting torque—low starting current type which is similar to the previous type except that a low initial current is required to start it.

Wound rotor induction motors which are characterized by heavy starting torque with relatively low starting current and smooth acceleration. Speed control is effected by means of a variable resistor in the secondary circuit which permits decreasing the speed to about 50 per cent of synchronous speed. Beyond this point, the motor becomes unstable.

High-frequency induction motors are used where fairly constant high-speed is required. Some form of frequency changer is also necessary when the power supply is at 60 cycles or less.

Synchronous motors which are characterized by exceptionally constant speed under all loads within their capacity and starting characteristics similar to those of squirrel-cage motors (where a squirrel-cage winding is provided). They are often used to make correction for the low power factors of other motors on the system.

Repulsion-induction motors which are characterized by high starting torque and low starting current with practically constant-speed operation.

Split-phase motors which are characterized by comparatively high starting current and low starting torque. They are usually made in fractional horsepower sizes. In larger sizes, their excessive starting current makes them undesirable.

Capacitor motors which are characterized by extremely quiet operation and good starting torque. Speed control may be secured through variation of the voltage applied to the motor terminals. Usually, a transformer performs this function. They are useful chiefly in applications which require motors up to 5 horsepower.

Adjustable-speed brush-shifting motors which are characterized by constant torque with a wide speed range at full load. Speed control is effected by shifting the brush position.

Series-wound universal motors which are characterized by high speed which varies with the load and ability to operate on either alternating or direct current. They are used in fractional horsepower sizes.

Multi-speed motors are also provided in the squirrel-cage, wound-rotor, and synchronous types. These operate at two, three, or four different fixed speeds with varying characteristics, according to their construction.

Motor Selection, Direct Current. For direct-current operation, the following general types of motors are available:

Series motors that are characterized by heavy starting torque and inverse variation of speed with load, often resulting in dangerous speeds at light loads. Speed control is effected by insertion of a rheostat in series with the armature, but this will not prevent variation of speed with the load. Connection to the driven machine is usually direct or through gears rather than by belting.

Shunt motors which are characterized by practically constant speed with a drop of only 10 to 12 per cent from no load to full load. Speed control is effected by (1) armature control in which a resistance is placed in the armature circuit for reducing the speed down to about 50 per cent of that at full load with constant torque, and (2) field regulation by introducing resistance in the shunt field circuit which increases the speed up to 150 to 200 per cent of that at full load, with decreasing torque.

Compound motors which have characteristics similar to both series and shunt motors, i.e., good starting capacity and fairly constant speed. Speed control may be obtained by either field or armature control. The customary range extends from about 75 to 200 per cent of normal full-load speed.

Motor Speed Classification. Electric motors may, for convenience, be classified with reference to their speed characteristics as follows: (1) Constant-speed motors, the speed of which is

either constant or does not vary materially; such as synchronous motors, induction motors with small slip, and ordinary direct-current shunt motors. (2) Multi-speed motors (two-speed, three-speed, etc.), which can be operated at any one of several distinct speeds, these speeds being practically independent of the load, such as motors with two armature windings, or induction motors in which the number of poles is changed by external means. (3) Adjustable-speed motors, in which the speed can be varied gradually over a considerable range, but when once adjusted remains practically unaffected by the load, such as shunt motors designed for a considerable range of speed variation. (4) Varying-speed motors, or motors in which the speed varies with the load, ordinarily decreasing when the load increases, such as series motors, compound-wound motors, and series-shunt motors. As a sub-class of varying-speed motors may be cited adjustable varying-speed motors, or motors in which the speed can be varied over a considerable range at any given load, but, when once adjusted, varies with the load, such as compound-wound motors arranged for adjustment of speed by varying the strength of the shunt field.

Motors, Protection Equipment. Protection of electric motors is accomplished by the use of various magnetically, thermally, and mechanically operated relays which may either be separate from or a part of the motor or starting or regulating equipment. Such protective devices fall under the headings of:

Low-voltage release devices which are magnetic relays that cause interruption of the power feed when the line voltage falls below a predetermined point but which do not prevent the re-establishment of power connections to the motor; consequently, they are used only where motors may be automatically re-started without damage.

Low-voltage protective devices which not only cause interruption of the power feed, but prevent reconnection until some form of starting mechanism is again manually actuated. To avoid unwanted disconnections on momentary circuit interruptions or voltage dips, a delayed-time mechanism or holding device is usually incorporated.

Overload protective devices which provide for circuit interruption when the overload exceeds a predetermined value as in the case of a cartridge fuse, or when the overload exceeds such a value for a predetermined length of time as in the case of certain time-delay devices.

Phase protective devices which are particularly necessary on polyphase motors of medium size and larger where the failure of any phase may cause a reversal of rotation and consequent damage. But even if reversal should not occur, a phase failure would cause an overload to be placed on the other windings re-

maining in the circuit, and, hence, some protective device is usually provided.

Thermal protective devices provide for circuit interruption whenever overheating occurs, whether due to an overload or a combination of heavy load and high ambient temperature.

Hazardous Location Protection: Both control equipment and motors may need to be of special design when used in hazardous locations (which see), and for this purpose special enclosures are built which may be dust-tight, water-tight, waterproof, drip-proof, splash-proof, weather-proof, gas-proof, or explosion-proof. As used for such equipment, the suffix "tight" is applied to a control or motor which is so constructed that its enclosure will exclude the specific material guarded against from entrance. The suffix "proof" applies to apparatus which is so constructed, protected or treated that its successful operation is not interfered with when subjected to the specified injurious material or condition of operation.

Motor Standards. To assist in the universal application and interchangeable mounting of motors to all types of equipment, the National Electrical Manufacturers Association have adopted standard dimensions for mounting, which include the spacing of bolt holes in the foot of the motor, the distance from the bottom of the foot to the center line of the motor shaft, the size of the foot, the size of the pulley, and other dimensions likely to be required by designers or manufacturers of motor-driven equipment. Also given are standard frame sizes and standard horsepower and speed ratings for various types of motors. These dimensions and speed ratings may be found in MACHINERY'S Handbook.

Motors Under Automatic Control. For some motor applications, it is desirable to have the starting-box automatically operated, or capable of being started by pushing a button or closing a switch at some remote point. Automatically operated control equipments are generally of the magnetic contactor type, including interlocking devices and current limiting relays. Some device, either hand or automatically operated, is used to close the main switch connecting the motor to the line, all the resistance being inserted in the secondary circuit. The current limiting relays are held open by the sudden inrush of current, and none of the secondary contactors can be energized until, at partial speed of the motor, the current falls to some predetermined value. The interlocks control the sequence at which the contactors are to close, and thus short-circuit and cut out the resistance; thus with this type of automatic control the acceleration is governed entirely by the safe value of the current, and the equipment is,

therefore, protected from abuse. The master controller or control switch may be placed in any location remote from the motor and the control panel. In connection with motor-driven pumps and air compressors, the self-starter finds one of its widest fields of usefulness. By means of a switch operated by a float in the tank, the circuit to the motor is automatically opened and closed through the self-starter whenever the water in the tank reaches a predetermined high or low level. In compression tank systems, and when used with air compressors, a pressure gage is substituted for the float switch, the circuit being made and broken as the needle, or indicator, moves back and forth between two fixed points.

Motor Types. See Compound-wound Motors; Commutator Motors, Alternating Current; Induction Motors, Polyphase; Series-wound Motors; Shaftless Motors; Shunt-wound Motors; Single-Phase Motors; Synchronous Motors; and Universal Motor.

Mottling. Mottling is a method for obtaining a mottled coloring effect on metal parts. On steel, such colors may be obtained by heating the object to a cherry-red heat for several minutes in cyanide of potassium and then dipping it in clear water, moving it about in the bath vigorously.

Muff Coupling. A muff coupling is one that is split longitudinally into two halves which are bolted together over the joint of the two shafts. A key and keyway are provided in one half of the coupling and in the shafts, to provide a positive drive.

Muffle Brazing. This is a method of brazing in which the parts to be united are enclosed in a tube or muffle, insuring uniform heating and clean, smooth surfaces. This method is especially applicable to the brazing of alloys the melting temperatures of which are nearly the same as that of the spelter solder. See also Brazing.

Muffle Furnaces. The principle of muffle furnaces is to improve the quality of the steel by keeping the heated work separated from the combustion gases by the use of a "muffle" or separate container into which the work is placed. There is no doubt that this is advantageous under the usual conditions of firing a furnace. However, with a properly designed furnace and proper burning of fuel, the combustion gases may be made practically harmless to the steel. The muffle type of furnace is apt to have more oxygen in contact with the metal than the open heating-chamber type as the result of sealing the work. To prevent oxidation, charcoal is often placed in the muffle to generate a

protective gas that will burn up the oxygen and thus prevent the steel from scaling.

Mule Pulleys. This term is applied to the idler pulleys used in conjunction with a right-angle belt drive which is so arranged that the belt in passing from the driving pulley to the driven pulley, must be guided or supported by idlers.

Mult-Au-Matic. This is a trade name applied to a vertical, multiple, automatic machine tool of the station type. This machine has work-holding chucks with tool slides and tools above for performing the necessary operations progressively as the chucks and work index periodically from one station or tool position to the next. Thus the tools of each position operate simultaneously and every indexing movement brings a finished part to the first position, where it is replaced with a rough casting or forging.

Multi-Ply. Liquid rubber which is applied in laminations to the sides of metal tanks to be coated until the desired thickness is obtained. These several coats coalesce during the vulcanizing process into a single sheet, bonded or almost "welded" to the walls of the tank. Especially applicable to plating and chemical tanks. Provides a continuous, seamless, lap-free, and unbroken lining.

Multi-Speed Winding. This type of winding consists of two or more separate windings for alternating-current motors, which can be so connected as to change the polar grouping. In this way a number of different speeds can be obtained in the motor.

Multiple-Crank Presses. Power presses having a multiple crank drive are made in many different designs and sizes. The double crank drive is applied to most presses included in this class, although three- and four-crank presses, varying in width between the housings from 3 to 10 feet, are used quite commonly. The multiple-crank design is employed for operating large cutting, bending, stamping, and forming dies or gangs of punches and dies extending over a large area. This kind of press is also adapted for punching holes in wide sheets, when it is not desirable to use a press having a deep-throated frame. Multiple-crank presses are used for the manufacture of sheet iron and steel goods, such as steel and wrought-iron ranges, shingles, panelled ceilings and sidings for buildings, cornice work, metal furniture, automobile parts, metal radiators, etc. The larger sizes are employed for heavy stamping, cutting, perforating, forming, and bending operations in connection with the manufacture of heavy metal parts of automobiles and other lines of work.

Multiple-Plunger Press. The multiple-plunger press is designed for producing by a series of simultaneous operations a complete article at every revolution of the press. It is constructed in various styles and sizes, the number of plungers varying from 3 to 8. A design most extensively used for the general run of small work is a six-plunger machine. This press can be used for such operations as blanking, cupping, piercing, forming, embossing, stamping, curling, bending, redrawing, perforating, clipping, etc., and, in fact, almost any like operation that is performed on sheet metal. It can also be used when only three or more operations are required, by having the remaining plungers run idle. The multiple-plunger press was originated at the Waterbury Brass Co., Waterbury, Conn., in the year 1860, its inventor being Robert Cairns.

Muntz Metal. Muntz metal is a brass containing about 60 per cent of copper and 40 per cent of zinc. It is used in marine work for bolts and nuts not subjected to the action of salt water, and also for castings and fittings which are not subjected to salt water. The tensile strength is 40,000 pounds per square inch, and the elongation in two inches, 25 per cent. Experiments for determining the effects of heat-treatment on Muntz metal indicate that after annealing cold-drawn bars to 500 degrees C. (about 930 degrees F.), for 48 hours, the tensile strength is about 50,000 pounds. The metal is remarkably immune from oxidation during heating. It is not advisable to anneal at a higher temperature than that mentioned.

Muriatic Acid. Muriatic acid is an aqueous solution of hydrogen chloride, the chemical formula of which is HCl; chemically known as hydrochloric acid.

Muscovite. See Mica.

Mushet Steel. Mushet steel is a tool steel discovered in 1868 by Robert F. Mushet. This steel is known as *self-hardening*, and also as *air-hardening*, steel. Mushet steel contains a high percentage of tungsten and has the property of becoming hard, after heating, without the usual quenching. It is an early type of high-speed steel.

Music Wire. Music or piano wire is made from a high grade of steel in diameters of from 0.004 to 0.180 inch. There are many different gages to which this class of wire is made, but the piano wire gage designated as the "American Steel & Wire Co.'s Music Wire Gage" is adopted as standard for piano wire in the United States, upon the recommendation of the U. S. Bureau of Standards. The smaller diameters of music wire have an ultimate

tensile strength of from 300,000 to 340,000 pounds per square inch. The composition of this wire is as follows: Carbon, 0.57 per cent; silicon, 0.09 per cent; sulphur, 0.011 per cent; phosphorus, 0.018 per cent; manganese, 0.425 per cent.

Mycalex. "Mycalex," a composition of ground mica and lead borate, is an insulating material used for radio high-frequency insulators. It has better insulating properties than porcelain, is light gray in color and has a metallic ring. It is used in the manufacture of bases for radio transmitter tubes, for aerial insulators in high frequency work, and for numerous similar applications.

N

Nail-Making Machines. Nail-making machines are relatively simple, single-stroke, open-die headers. When the required length of wire has been fed, the open-dies close and the nail head is formed in one blow. As the heading hammer withdraws, the dies open and the wire is advanced the length of the nail. The dies again grip the material and clipping tools form the nail point and cut-off the wire. Enough wire is allowed to project beyond the face of the dies to form the head of the next nail.

Nail-making machines are capable of producing eight *d* nails at eleven per second, five *d* nails at fourteen per second, and two *d* nails at twenty per second. Fully automatic machines equipped with carbide tooling, magnetic conveyor belts, and safety shut-off systems, are capable of runs of 600 hours or more (more than 30 million five *d* nails)—stopping only to permit the placing of new coils of wire on the variable-speed feeding reels.

Napier Formula. The Napier formula for the discharge of saturated steam was proposed by S. D. Napier, an English engineer, as a result of carefully conducted experiments, made by him to test the accuracy of abstruse mathematical formulas of flow that had previously been relied upon, which formulas he found to be in error. Napier's tests indicated that the more intricate formulas modified to the simple formula, $W = (P \times A) \div 70$, would be nearly true in all cases where the initial pressure is 1 2/3 times the pressure of the gaseous medium into which steam may be discharged, and the formula has been extensively verified and is accepted as substantially correct for such conditions. In the formula, W is the number of pounds of steam discharged per second from an aperture; P is absolute pressure (absolute pressure is taken, because the physical properties of steam depend upon absolute pressure and not upon gage pressure, which is accidental and depends on the variable pressure of the atmosphere); A is the area in square inches of the aperture.

Napierian Logarithms. The *Napierian* or *hyperbolic* logarithms differ from the common logarithms in that the base of the hyperbolic logarithms is 2.71828, whereas the base of the common logarithms is 10. The name "Napierian" logarithms is derived from the inventor of this mathematical time-saver, John Napier, a Scotchman, born in 1550. The work in which the logarithms were first described appeared in 1614.

Napier Motion. When a gear or pinion is in mesh with a single rack and rotates in one position, obviously both the gear and rack must reverse their direction of motion at the end of each stroke if a reciprocating motion is to be imparted to the driven member to which the rack is attached. The gear, however, may rotate continuously in one direction if it is arranged to engage the upper and lower sides of a rack designed especially to permit such engagement. A mechanism of this type, known as the Napier motion and also as "mangle gearing," has been used for imparting a rectilinear motion to the tables of flat-bed printing presses.

National Standard Screw Threads. See American Standard Screw Thread System.

National Wire Gage. See Steel Wire Gage.

Native Copper. Native copper, also known as malleable copper and virgin copper, is practically pure natural copper, having all the properties of refined metal. It is mined extensively in the Lake Superior district, and in Bolivia.

Natural Alloy Steel. Natural alloy steel is so designated because of the fact that this class of steel is manufactured from an ore in which nickel and chromium are alloyed by nature. About 1900, this ore was discovered at Mayari and Moa in the Province of Oriente, in the eastern part of Cuba. These ores show a remarkable uniformity of composition and cover some 25,000 acres The various grades of steel into which this ore is manufactured contain from 1.00 to 1.50 per cent of nickel; from 0.20 to 0.70 per cent of chromium; from 0.15 to 1.50 per cent of carbon; and from 0.50 to 0.80 per cent of manganese; the silicon is kept below 0.20 per cent, and the phosphorus and sulphur, below 0.04 per cent. These two latter elements, however, seldom reach 0.035 per cent, and a phosphorus content that is below 0.02 per cent is often obtained. These natural alloy steels are made by the open-hearth process and are, in the heat-treated condition, equal to 3½ per cent nickel steel. In some ways, they are superior to this steel and especially is this true of the grade that contains the higher percentages of chromium, or when they are manufactured into parts that have a comparatively large sectional area. They are also cheaper than the nickel steels made by the same process. Natural alloy steel can be hammered, rolled, drop-forged, pressed, stamped, or machined with the same ease and at the same temperatures as carbon steel; no special precautions are necessary. Natural alloy steels are largely used in the manufacture of automobile parts. One grade containing as low as 0.15 per cent of carbon is used for casehardened parts. Speed change-gears, differential gears, etc., are made from steel containing 0.20 per

cent of carbon. The grades containing high percentages of carbon are used for spindles, rear axles, crankshafts, and transmission gears. Natural alloy steels, like all other steels, will attain the highest strength only when properly heat-treated. In the untreated or annealed state, they show a tensile strength and elastic limit that is from 8000 to 10,000 pounds per square inch higher than carbon steels of the same carbon content, but, when properly heat-treated, they compare favorably with other alloy steels.

Natural Cement. This cement is made by burning mixtures of clay and carbonate of lime, or by calcination of a silicious limestone containing magnesia, and may be considered as Portland cement of inferior quality. Natural cement is a good building material for ordinary purposes, but is not as suitable for heavy and important concrete constructions as Portland cement. Natural cement does not develop its strength as quickly and is not as uniform in composition as Portland cement. It is satisfactory to use, however, in massive masonry, where weight rather than strength is the essential feature.

Nautical Measure. 1 league = 3 nautical miles; 1 nautical mile (often called "knot") = 6080.2 feet = 1.1516 statute miles; one degree at the equator = 60 nautical miles = 69.096 statute miles; 360 degrees = 21,600 nautical miles = 24,874.5 statute miles = circumference of earth at the equator.

Naval Brass or Bronze. This alloy, which is also known as "Tobin Bronze," is used for applications requiring a stronger, tougher, and less corrodible material than commercial brass rod.

S.A.E. Composition No. 73: Copper, 59 to 62; tin, 0.50 to 1.50; iron, max., 0.10; lead, max., 0.30; other impurities, max., 0.10 per cent; zinc, remainder.

Physical Properties: Minimum tensile strength in pounds per square inch varies from 54,000 to 62,000, depending upon the diameter of the rod; yield point, from 22,000 to 31,000; elongation, from 25 to 40 per cent. Hot-pressed forgings should have an ultimate strength of 54,000, a yield point of 22,000 pounds per square inch, with an elongation in 2 inches of 25 per cent.

Naxos Emery. This is an abrasive obtained from Naxos, an island in the Ægean Sea. It is considered the best natural emery obtainable, containing about 63 per cent of crystalline alumina, which is the cutting material.

Needle Valve. A needle valve is provided with a long tapering point in place of the ordinary valve disk. The tapering point permits fine gradation of the opening. At times called a *needle point valve.*

Negative Numbers. Ordinary numbers may be considered positive and negative in the same way as the graduations on a thermometer scale. When we count 1, 2, 3, etc., we refer to the numbers that are larger than 0 (corresponding to the degrees *above* the zero point), and these numbers are called positive numbers. We can conceive, however, of numbers extending in the other direction; numbers that are, in fact, less than 0 (corresponding to the degrees below the zero point on the thermometer scale). As these numbers must be expressed by the same figures as the positive numbers, they are designated by a minus sign placed before them. For example, -3 means a number that is as much less than, or beyond, 0 in the negative direction as 3 (or, as it might be written, $+3$) is larger than 0 in the positive direction.

A negative value should always be enclosed within a parenthesis whenever it is written in line with other numbers; for example:

$$17 + (-13) - 3 \times (-0.76).$$

In this example (-13) and (-0.76) are negative numbers, and, by enclosing the whole number, minus sign and all, in a parenthesis, it is shown that the minus sign is part of the number itself, indicating its negative value. It must be understood that in the expression $7 - 4$, the value 4 is not a negative number, although it is preceded by a minus sign. In this case the minus sign is simply the sign of subtraction, indicating that 4 is to be subtracted from 7; but 4 is still a positive number or a number that is larger than 0.

Negative numbers are most commonly met with in the use of logarithms and natural trigonometric functions. The following rules govern calculations with negative numbers.

(1) When adding two or more positive or two or more negative numbers, their sum is equal to the sum of their absolute values and has the same sign as that of the numbers being added.

Example:

$$2 + 8 + 10 = 20$$
$$(-3) + (-6) + (-4) = -13$$

(2) When adding a positive and a negative number, their sum is equal to the difference of their absolute values and has the same sign as the number having the larger absolute value, thus:

Example:

$$-6 + 2 = -4$$
$$9 + (-3) = 6$$

(3) When adding several positive and negative numbers, first add the positive and negative numbers separately and then add their respective sums. Follow Rule 2 for this last operation.

Example:

$$4 + (-6) + 8 + (-2) = 12 + (-8) = 4$$

(4) When subtracting one positive number from another positive number or one negative number from another negative number, the remainder is equal to the difference of their absolute values and has the same sign as the numbers being subtracted if the minuend has a larger absolute value than the subtrahend but the opposite sign if the minuend has a smaller absolute value than the subtrahend.

Examples:

$$8 - 10 = -2$$
$$(-6) - (-4) = -2$$
$$(-6) - (-9) = 3$$

(5) When subtracting a negative number from a positive number or vice versa, the remainder is equal to the sum of their absolute values and has the same sign as the minuend.

Examples:

$$8 - (-2) = 10$$
$$(-2) - 3 = -5$$

(6) When multiplying two positive or two negative numbers together, their product is equal to the product of their absolute values and is positive.

Examples:

$$18 \times 16 = 288$$
$$(-9) \times (-27) = 243$$

(7) When multiplying a positive and a negative number together, their product is equal to the product of their absolute values and is negative.

Example:

$$182 \times (-16) = -2912$$

(8) When dividing a positive number by a positive number, or a negative number by a negative number, their quotient is equal to the quotient of their absolute values and is positive.

Example:

$$196 \div 28 = 7$$
$$(-1064) \div (-76) = 14$$

(9) When dividing a positive number by a negative number or vice versa, their quotient is equal to the quotient of their absolute values and is negative.

Example:

$$5190 \div (-346) = -15$$
$$-2698 \div 19 = -142$$

Negative Rake. This term is sometimes applied to turning or other metal-cutting tools which are so ground that the tool has less keenness than one ground to a rake angle of zero. See Rake of Metal-cutting Tools.

Neon. Neon is a gaseous chemical element, the symbol of which is Ne, and the atomic weight, 20.2. Neon occurs in very small quantities in the earth's atmosphere, and was first discovered in 1898. It is a colorless gas having a specific gravity (compared with air as unity) of 0.674. It becomes liquid at a temperature of —243 degrees C. (—405 degrees F.), and solidifies at a temperature of —253 degrees C. (—423 degrees F.). Neon occurs in the air in greater proportions than any of the other rare gases, except argon. The presence in air is to the extent of from 1 to 2 volumes in 100,000 volumes of air.

Neon Lamps. See Vapor Lamps.

Neoprene. A synthetic rubber with the elastic properties of natural rubber, but impervious to alcohol, anti-freeze solutions, automobile radiator cleaning compounds, oils, and chemicals in general. Used for many purposes where natural rubber products have failed to give satisfactory service, because of having less tendency to crack when repeatedly stretched and bent at high temperatures.

Neutral Axis. The neutral axis of a beam subjected to a bending stress is that line or plane in which the fiber stress equals zero. Strictly speaking, the neutral axis should be simply a line, and when considering the whole plane in which the fiber stress equals zero, it should be referred to as the *neutral plane;* but this is seldom done in engineering literature, the expression "neutral axis" being very frequently used in place of "neutral plane." If the beam is of a homogeneous material and subjected to bending stresses only, the neutral axis passes through the center of gravity of the cross-section. If the beam is subjected to combined flexure and direct stress, then the neutral axis will not pass through the center of gravity. All engineering materials may be considered as homogeneous except beams made from reinforced concrete, in which the neutral axis will not be located at the center of gravity of the cross-sectional area.

Neutral Conductor. When a polyphase circuit has a neutral conductor, it may be designated as that conductor which is intended to carry a much smaller current than the other conductors, provided these others are all expected to carry approximately equal currents. In a polyphase circuit having a neutral conductor, the potential differences between it and each of the other

conductors are intended to be equal. In a three-phase circuit, a neutral conductor would be a fourth conductor.

Neutral Flame. Ordinarily in welding metals by the autogenous process, it is essential to so regulate the gases used that a neutral or non-oxidizing flame is obtained. If oxygen and acetylene are used complete combustion is effected when one volume of acetylene burns with two and one-half volumes of oxygen. According to one authority the highest flame temperature is produced by a mixture at the torch of one volume of acetylene with one volume of oxygen, the surrounding air supplying the additional one and one-half volumes of oxygen necessary to complete combustion. The flame produced from such a mixture is neutral in that it does not produce chemical changes detrimental to the metal with which it is in contact. To adjust a torch for a neutral flame, first adjust so that the flame shows a secondary or middle cone characteristic of excess acetylene; then reduce the amount of the acetylene until this secondary cone just disappears.

Neutral Plane. A neutral plane is the plane in a beam subjected to a load tending to bend it in which neither compression nor tension will occur. See Neutral Axis.

Neutron. A neutron is an elementary particle (constituent of matter). Neutrons and protons make up the nucleus of an atom, except in hydrogen which has only one proton as a nucleus. It has approximately the same mass as a proton but is electrically neutral.

Newton's Law of Motion. The first clear statement of the fundamental relations existing between force and motion was made in the seventeenth century by Sir Isaac Newton, the English mathematician and physicist. It was put in the form of three laws, which are given as originally stated by Newton: I. Every body continues in its state of rest, or uniform motion in a straight line, except in so far as it may be compelled by force to change that state; II. Change of motion is proportional to the force applied and takes place in the direction in which that force acts. III. To every action there is always an equal reaction; or, the mutual actions of two bodies are always equal and oppositely directed.

Nib. The term nib is sometimes applied to the gaging end of a plug gage consisting of a handle into which the nib or gaging end is inserted. The nib may be of plain cylindrical form for gaging the diameters of holes, or it may be a threaded form for gaging screw thread sizes.

Nibbling Machine. The "nibbling machine" is so named because it is used for cutting sheet metals to any desired outline, by means of a rapidly reciprocating punch which takes numerous small cuts. The punch is of small size and enters a die held in the bedplate. Sheet steel can be cut out to the contour of layout lines or superimposed templets. This machine is intended for use where conditions do not warrant making a blanking punch and die for use on a power press.

Nichrome. "Nichrome" is the trade name of an alloy composed of nickel and chromium, which is practically non-corrosive and far superior to nickel in its ability to withstand high temperatures. Its melting point is about 1550 degrees C. (about 2800 degrees F.). Nichrome shows a remarkable resistance to sulphuric and lactic acids. In general, nichrome is adapted for annealing and carburizing boxes, heating retorts of various kinds, conveyor chains subjected to high temperatures, valves and valve seats of internal combustion engines, molds, plungers and conveyors for use in the working of glass, wire baskets or receptacles of other form that must resist the action of acids, etc. Nichrome may be used as a substitute for other materials, especially where there is difficulty from oxidation, pitting of surfaces, corrosion, change of form, or lack of strength at high temperatures. It can be used in electrically-heated appliances and resistance elements. Large plates of this alloy are used by some manufacturers for containers and furnace parts, and when perforated, as screens for use in chemical sifting and ore roasting apparatus, for services where temperatures between 1700 degrees F. and 2200 degrees F. are encountered.

Strength of Nichrome: The strength of a nichrome casting, when cold, varies from 45,000 to 50,000 pounds per square inch. The ultimate strength at 200 degrees F. is 94,000 pounds per square inch; at 400 degrees F., 91,000 pounds per square inch; at 600 degrees F., 59,000 pounds per square inch; and at 800 degrees F., 32,000 pounds per square inch. At a temperature of 1800 degrees F., nichrome has a tensile strength of about 30,000 pounds per square inch, and it is tough and will bend considerably before breaking, even when heated red or white hot.

Nichrome in Cast Iron: Because of the irregularity of the castings, the numerous cores required, and the necessity for sound castings, gray iron with a high silicon content has been the best cast iron available to the automotive industry. Attempts have been made to alloy this metal in such a way that the strength and hardness would be increased, but considerable difficulty has been experienced in obtaining uniform results. Nickel has been added to the cupola with success, but in the case of automotive castings,

where a large quantity of silicon is present, the nickel has combined with the silicon in forming large flakes of graphite, which, of course, softens the product. To offset this, chromium has also been added, but it has been uncertain just what the chromium content of the poured mixture should be, as a considerable amount of the chromium oxidizes.

Nichrome (Grade B) may be added to the ladle to obtain chromium and nickel in definite controllable amounts. The analysis of this nichrome is, approximately: Nickel, 60 per cent; chromium, 12 per cent; and iron, 24 per cent. It is claimed that the process produces castings of closer grain, greater hardness, greater resistance to abrasion, increased durability, improved machinability, and decreased brittleness. Nichrome-processed iron is suitable for casting internal-combustion engine cylinders; electrical equipment, where a control of the magnetic properties is desired; cast-iron cams; iron castings of thin sections where machinability and durability are factors; electrical resistance grids; pistons; piston-rings; and water, steam, gas, and other valves.

Nickel. Nickel is a grayish-white, malleable, ductile metal. In dry air, it remains unchanged, but oxidizes slowly in moisture in which acids are present. It resists the action of caustic soda, caustic potash, and concentrated nitric acid, but is readily dissolved by dilute nitric acid and aqua regia. Dilute hydrochloric acid and dilute sulphuric acid attack it very slowly. Nickel is used to a very large extent in the industries, especially in the manufacture of domestic utensils and for nickel-plating; it is also used for coins, and a number of alloys. Steels containing a small percentage of nickel have properties far superior to those of ordinary steel, while steels containing a very high percentage of nickel have been manufactured for special purposes. Nickel is obtained mainly from garnierite, the largest deposit of which is in New Caledonia, and from pyrrhotite, which is found principally in Canada, Germany, Sweden, and Norway. It is also secured from the by-products obtained by treating many pyrite and chalcopyrite deposits for sulphur or copper. The method of extracting the nickel depends upon the composition of the ore.

The specific gravity of nickel varies according to the method used for obtaining the metal; it has been found to be as low as 8.3 and as high as 9.25; an average commercial value is 8.8, giving a weight per cubic inch of 0.318 pound. Pure nickel melts at 1452 degrees C. (2646 degrees F.). The melting point of commercial nickel, however, varies anywhere from 1400 to 1600 degrees C. (from about 2550 to 2900 degrees F.). The specific heat averages 0.108 between 60 and 212 degrees F., and increases with an increase in the temperature. The thermal conductivity of

nickel equals 14.2 (silver = 100) and the electrical conductivity, 12.9 (silver = 100). The linear expansion per unit length, per degree F., equals 0.00000695. Nickel is magnetic, but loses its magnetism when heated, and becomes entirely non-magnetic at a temperature of about 650 degrees F.

Nickel Alloy for Resisting Acids. The resistance of nickel to acids is considerably increased by an addition of tantalum. Ordinarily from 5 to 10 per cent may be added, but the resistance increases with an increasing percentage of tantalum. An alloy of nickel with 30 per cent tantalum, for example, can be boiled in aqua regia or any other acid without being affected. The alloy is claimed to be tough, easily rolled, capable of being hammered or drawn into wire. The nickel loses its magnetic quality when alloyed with tantalum. The alloy can be heated in the open air at a high temperature without oxidizing. The method of producing the alloy consists in mixing the two metals in a powdered form, compressing them at high pressure, and bringing them to a high heat in a crucible or quartz tube in a vacuum. For general purposes, the alloy is too expensive.

Nickel-Chromium Steel. Nickel-chromium steel has, by both laboratory and practical tests, proved to be a very high grade steel. It is used on various classes of machinery that require a steel of high tensile strength, high elastic limit, and a great resistance to shock and torsional stresses. The properties which are given to steel by nickel and chromium, when used separately, are accentuated when nickel and chromium are added at the same time. A steel is then produced that possesses the very highest qualities that can be obtained with regard to strength, hardness, and ductility. The different combinations or percentages of the components of nickel-chromium steels are as varied as their makers. Thus nickel is used in percentages of from 1 to 5; chromium, from 0.5 to 5; carbon, from 0.25 to 0.45; silicon, when used, from 0.5 to 3; manganese, from 0.25 to 1.

Nickel-chromium steel must always be heat-treated in order to bring out the latent qualities of the annealed steel. It should be annealed after it has been worked and before heat-treatment, in order that it may return to its natural state of repose, as machining, forging, hammering, etc., is liable to throw it out of its homogeneity. The well-known Krupp armor-plate steel is a nickel-chromium steel containing about 3.25 per cent of nickel, 1.5 per cent of chromium, and 0.4 per cent of carbon. The value of this steel lies particularly in the fact that it does not crack even when deeply penetrated by a projectile. It is also used, to a great extent, for gears, and is the highest grade of steel on the market for this purpose. Another use is for automobile parts which require great strength and reliability.

S.A.E. Nickel-chromium Steels: Nickel-chromium steels represent an important class in the automotive industry. The S.A.E. specifications include four different groups of compositions, according to the nickel-chromium content.

Nickel Plating. See Electro-plating.

Nickel Silver. See German Silver.

Nickel Steel. Nickel steel usually contains from 3 to 3.5 per cent of nickel (seldom over 5 per cent) and from 0.20 to 0.40 per cent of carbon. It combines great tensile strength and hardness with a high elastic limit and ductility. When properly heat-treated, it is much stronger than tool steel, but should not be used without heat-treating. Because of its combination of ductility, strength, and hardness, it is extensively used for armor plate, because it does not crack when perforated by a projectile. It is also used for ammunition, bridge construction, rails, etc., and in automobile building. An advantage claimed for nickel steel for rails is its increased resistance to abrasion. On sharp curves, it is estimated that a nickel-steel rail will outlast four ordinary rails. The combination of ductility with a high elastic limit makes this steel also valuable for shafting, especially for marine purposes where high and sudden stresses are frequently imposed upon the propeller shafting. It it suitable for parts requiring great strength, ductility, elasticity, abrasion and corrosion resistance—for example, axles, spindles, light-weight frames (such as for bicycles), rivets, gun barrels, armor plate, etc. It is easily cast and forged. When alloyed with chromium or vanadium, it is largely used for crankshafts, special spindles, automobile axle parts, etc. The strongest nickel steels are made from low-carbon steels.

Nickel steel can be purchased in almost any percentages of nickel up to 35 per cent, and with the carbon component varying between 0.10 and 1 per cent. If nickel is added to steel in any percentage not exceeding 8 per cent, the tensile strength and the elastic limit of the steel will increase with the percentage of nickel. If the percentage of nickel is above 8 per cent, but less than 15 per cent, its effect on the steel becomes entirely neutralized and brittleness is produced. If the nickel percentage, however, is above 15 per cent, then the strength and elasticity become practically equal to that of the nickel steels with percentages of nickel less than 8 per cent. If the nickel percentage is increased above 20 per cent, the strength and elastic limit gradually decrease, but the elongation increases. The nickel in S.A.E. compositions varies from 3.25 to 5.25 per cent.

Nigrosine Paper. Nigrosine paper, also known as black-print paper, is a material used for obtaining black lines on a white background by the process of blueprinting.

Nikrome M. An alloy steel containing from 2 to 2.5 per cent nickel; from 0.90 to 1 per cent chromium; and from 0.40 to 0.50 per cent molybdenum. Minimum guaranteed properties: Tensile strength, 110,000 pounds per square inch; yield point, 90,000 pounds per square inch; elongation in 2 inches, 16 per cent; reduction of area, 47 per cent. Especially intended for heavy-duty parts, such as axles, shafts, bolts, studs, etc., made to large dimensions—approximately 5 to 8 inches in diameter. The material can be so heat-treated as to be practically uniform in hardness from surface to center.

Nilvar. A nickel-iron alloy that has the lowest coefficient of expansion of any metal at temperatures up to 392 degrees F. Suitable for applications where dimensions must be maintained at varying temperatures, as, for example, in rotor and stator plates of variable condensers in ultra high-frequency radio equipment, bimetallic strip, and length standards.

Nipples. Nipples are short pieces of standard pipe threaded on each end. When the threads run together at the center, the term "close nipple" is used; if a small amount of unthreaded surface is left in the center, the name used is "short nipple." Longer nipples are classified as "long" and "extra long," the latter varying from 4 to 12 inches, the length increasing by even inches. A *shoulder nipple* is a nipple of any length, which has a portion of pipe between two pipe threads. Generally, however, it is a nipple about halfway between the length of a close nipple and a short nipple. A *space nipple* has a portion of pipe or shoulder between the two threads. It may be of any length long enough to allow a shoulder. Nipples are either threaded right-hand or right- and left-hand.

Niter Bluing Process. This is a method for giving articles of iron and steel a fine blue color by immersing them in molten nitrate of potash (niter), often called "saltpeter."

Nitralloy. "Nitralloy" is a trade name applied to a number of special alloy steels which can be surface hardened by being subjected to the action of ammonia gas. See Nitriding Process.

Nitric Acid. Commercial nitric acid is yellow in color and has a specific gravity of about 1.4. It is one of the important mineral acids. It contains 68 per cent of the pure acid and boils at a temperature of 120.5 degrees C. (249 degrees F.). Nitric acid

attacks most metals readily, its action depending usually upon the temperature and the strength of the acid. Concentrated nitric acid gives off red fumes when the acid acts upon most metals. Nitric acid has no effect upon gold, platinum, iridium, or rhodium. It solidifies at a temperature of —53 degrees F.

Nitriding Process. Nitriding is a process for surface hardening certain alloy steels by heating the steel in an atmosphere of nitrogen (ammonia gas) at approximately 950 degrees F. The steel is then cooled slowly. Finish machined surfaces hardened by nitriding are subject to minimum distortion. The physical properties, such as toughness, high impact strength, etc., can be imparted to the core by previous heat-treatments and are unaffected by drawing temperatures up to 950 degrees F. The "Nitralloy" steels suitable for this process may readily be machined in the heat-treated as well as in the annealed state, and they forge as easily as alloy steels of the same carbon content. Certain heat-treatments must be applied prior to nitriding, the first being annealing to relieve rolling, forging, or machining strains. Parts or sections not requiring heat-treating should be machined or ground to the exact dimensions required. Close tolerances must be maintained in finish machining, but allowances for growth due to adsorption of nitrogen should be made, and this usually amounts to about 0.0005 inch for a case depth of 0.02 inch. Parts requiring heat-treatment for definite physical properties are forged or cut from annealed stock; heat-treated for the desired physical properties, rough machined, normalized, and finish machined. If quenched and drawn parts are normalized afterwards, the drawing and normalizing temperatures should be alike. The normalizing temperature may be below, but should never be above the drawing temperature.

Nitrogen. Nitrogen is a gas that forms approximately 79 per cent by volume, or 77 per cent by weight, of the atmosphere. The specific gravity of nitrogen (air = 1) is 0.967, and its atomic weight, 14.01. It liquefies at a temperature of —194 degrees C. (—317 degrees F.), and solidifies at a temperature of —210 degrees C. (—346 degrees F.). Its specific heat equals 0.244. Nitrogen neither burns nor supports the combustion of ordinary combustible materials. Nitrogen is produced in large quantities from atmospheric air in the commercial manufacture of nitric acid and nitrates.

Nitroglycerine. Practically all the higher explosives are based on "nitro," which is a chemical combination of glycerine and nitric acid, wherein the three hydroxyls of the glycerine are replaced by nitrogen oxide or some other organic substance with which the nitric acid can combine in a similar manner. Nitro-

glycerine is a heavy, thick, syrupy liquid. It has a specific gravity of 1.6, and its melting point is 13 degrees C. It has an intensely sweet taste, but is very poisonous, even in small quantities, when taken internally. The dose, when given internally, is only from 1/200 to 1/50 drop. Nitroglycerine is very sensitive to shock and friction, for which reason it is dangerous when frozen, as it must be thawed out before it can be used. A diluent has been found that will lower its freezing point without impairing its explosive power.

Noble Metal. This is a term applied to metals, such as gold, silver, and platinum. A *noble composition* is an alloy of two noble metals to which are added one or more metals as minor components.

Nodular Cast Iron. A distinguishing feature of this relatively new type of cast iron, also known as spheroidal graphite iron, is that the graphite is present in ball-like form instead of in flakes as in ordinary gray cast iron. The addition of small amounts of magnesium- or cerium-bearing alloys together with special processing produces this spheroidal graphite structure and results in a casting of high strength and appreciable ductility. Its toughness is intermediate between that of cast iron and steel and its shock resistance is comparable to ordinary grades of mild carbon steel. Melting point and fluidity are similar to those of the high carbon cast irons. It exhibits good pressure tightness under high stress and can be welded and brazed. It can be softened by annealing or hardened by normalizing or oil quenching and drawing.

Nodular cast iron can be cast in molds containing metal chills if wear-resisting surfaces are desired. Hard carbide areas will form in a manner similar to the forming of areas of chilled cast iron in gray iron castings. Surface hardening by flame or induction methods is also feasible. Nodular cast iron can be machined with the same ease as gray cast iron. It finds use as crankshafts, pistons, and cylinder heads in the automotive industry; forging hammer anvils, cylinders, guides, and control levers in the heavy machinery field, and wrenches, clamp frames, face-plates, chuck bodies, and dies for forming metals in the tool and die field.

Non-Ferrous Alloys. See Alloys, Non-ferrous; also various non-ferrous alloys, such as Brass; Bronze; Aluminum Alloys; Copper Alloys; Die-casting Alloys.

Non-Gran Bronze. Non-gran bronze is a gun-metal alloy. Its composition is copper, 86.5 per cent; tin, 11 per cent; and zinc, 2.5 per cent, with impurities which are less than 0.2 per cent. Non-gran bronze can be cast readily, and is also produced

in bar form. The solid sizes range from ½ inch to 5 inches in diameter, by eighths of an inch, and the cored sizes from ½ inch to 3 inches inside diameter, by eighths. It is a good metal for non-adjustable bushings where the original dimensions must be preserved through long service. It is also adapted, on account of its resistance to wearing action, for high-speed gears and worms, and for feed-nuts, valves, etc.

Properties: Weight, 0.31 pound per cubic inch; 536 pounds per cubic foot. Specific gravity, 8.6. Strength: tension, 37,000 pounds per square inch; compression, 19,500 pounds per square inch. Melting point, 2050 degrees F.

Non-Metal. A non-metal is a chemical element which does not possess the properties of a metal; that is, one that lacks metallic luster and which as a rule is nearly a non-conductor of heat and electricity; it is also electro-negative. There is no sharp demarcation, however, between metals and non-metals. The elements which cannot be defined strictly as being either the one or the other are known as *metalloids*.

Non-Spinning Rope. See Rope, Non-spinning.

Norbide. An extremely hard material having a compressive strength of 260,000 pounds per square inch; unaffected by the strongest acids and alkalies, and little affected by heat up to temperatures of 1800 degrees F. It is lighter than aluminum. Used in the cutting and lapping of cemented tungsten-carbides; for wire-drawing dies; pressure blast nozzles; and bearings for electric motors and high-speed spindles in grinding machines.

Nordberg Key. This is a taper key of circular cross-section. This type of key may be used for attaching handwheels to their shafts or for other similar light work requiring an inexpensive type of key. The Nordberg key has a taper of 1/16 inch per foot. The center of the key hole is located at the joint line between the shaft and hub. A small hole may be drilled first to prevent the larger drill from crowding over into the cast-iron hub. A general rule for determining the size of the key is to make the large key diameter equal to one-fourth the shaft diameter.

Normal Circular Pitch. The word "normal" is applied to the pitch of helical gears. The normal circular pitch is the distance between the centers of adjacent teeth measured along the pitch surface and perpendicular to the teeth; hence it is the shortest center-to-center distance.

Normal circular pitch = circular pitch in plane of rotation multiplied by cosine of helix angle. It also equals 3.1416 divided by normal diametral pitch. Circular pitch in plane of rotation = pitch circumference divided by number of teeth.

Normal Diametral Pitch. This is the diametral pitch corresponding to the normal circular pitch. Normal diametral pitch = number of teeth divided by product of pitch diameter multiplied by cosine of helix angle. It also equals 3.1416 divided by product of circular pitch in plane of rotation multiplied by cosine of helix angle. This is the diametral pitch of the cutter for a helical gear.

Normalizing. Normalizing of steel is a special case of annealing and may be defined as heating the steel above the critical temperature and cooling it freely in air. Annealing consists in heating at any elevated temperature and cooling at a relatively slow rate. It may be necessary, in the case of annealing, to hold the temperature for many hours or even days, whereas in normalizing it is sufficient to secure an even penetration of the heat throughout the material. Normalizing is intended to put the steel into a uniform, unstressed condition of proper grain size and refinement so that it will properly respond to further heat-treatments. It is particularly important in the case of forgings which are to be later heat-treated. Normalizing may or may not (depending upon the composition) leave steel in a sufficiently soft state for machining. In some cases annealing for machinability is preceded by normalizing, and the final result is much better than a simple anneal. The annealing temperatures are usually above the critical range, although not in general as high as those used in normalizing.

When using the lower carbon steels, simple normalizing is often sufficient to place the steel in its best condition for machining and will lessen distortion in carburizing or hardening. In the medium and higher carbon steels combined normalizing and annealing constitutes the best practice. For unimportant parts the normalizing may be omitted entirely or annealing practiced only when the steel is otherwise difficult to machine. Both processes are recommended in the heat-treatments (for S.A.E. standard steels) as representing the best metallurgical practice. The temperatures recommended for normalizing and annealing have been made indefinite in many instances because of the many different types of furnaces used in various plants and the difference in results desired.

Normal Pitch. The term "normal pitch" is applied to helical gears but it may have different meanings. This term, used in connection with gear design or gear-cutting practice, generally relates either to the *normal diametral* pitch or to the *normal circular* pitch, in which case either diametral or circular should be included in the term to indicate definitely which kind of pitch is intended. A helical gear also has a *normal pitch* which pertains

to the pitch of successive involute curves or tooth profiles. Involute curves developed from equidistant points along a given base circle, will be parallel or equidistant at all points if measured in a plane perpendicular to the gear axis and along any line that is tangential to the base circle. The normal pitch of an involute gear is the distance between the corresponding profiles of adjacent teeth when measured as described. The normal pitch also equals the length of the arc of the base circle, between the points where successive involutes originate.

Normal pitch equals circumference of base circle divided by the number of gear teeth.

Diameter of base circle equals pitch diameter multiplied by cosine of pressure angle in plane of rotation.

The normal pitch is often referred to as *base pitch.* The normal pitch is measured in the rotational plane of the gear, whereas the normal circular pitch is measured in the plane that is normal or perpendicular to the helix angle of the gear as explained in the paragraph Normal Circular Pitch. See also Normal Diametral Pitch.

Normal Pressure Angle. See Pressure Angle.

Normal Salt. In chemistry, a normal salt is a salt in which one atom of hydrogen in each molecule is replaced by a metal.

North Bolt. A North bolt is one which has a number of longitudinal grooves rolled into its body. This type of bolt is used largely on farming machinery and other agricultural appliances.

Numbers, Preferred. See Preferred Numbers.

Numerical Control. A system in which machine actions are controlled by the direct insertion of *numerical* data at some point; the data being information expressed by a set of numbers, or symbols that can only assume discrete values or configurations.

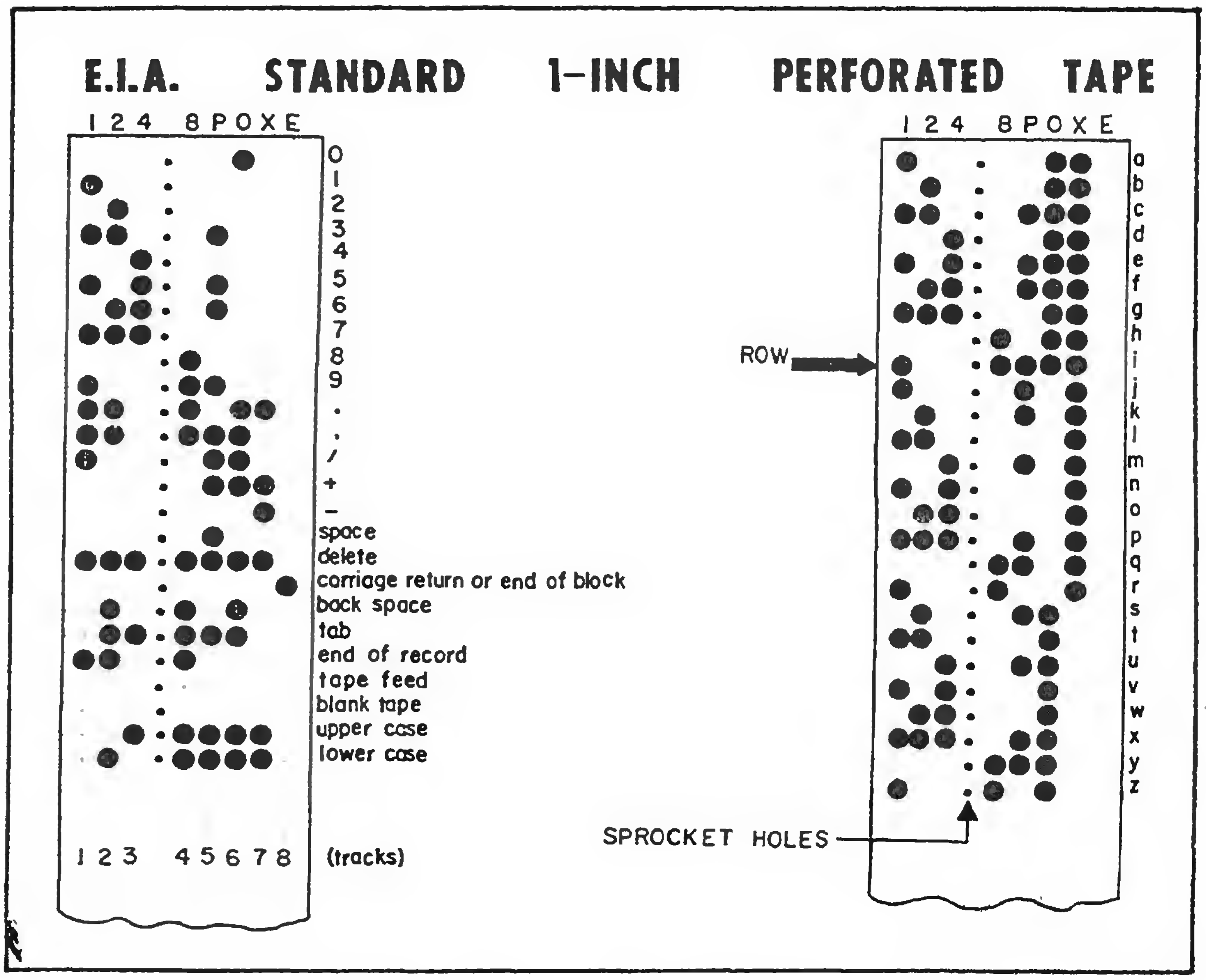
As applied to machine tools its use requires activity in four prime areas—product design, part programming, tape preparations, and the machine tool and its control system.

The product designer designs the part for numerical control production. His design is given to the part programmer in the form of engineering drawings. These drawings may have rectangular or Cartesian coordinate dimensioning so that the part programmer may easily transform the definition of the part shown by the drawing into information which will eventually command the machine tool through its control system.

Tape preparation consists of translating the part programmer's information and commands (in English letters and/or arabic numerals) to a form understandable by the machine control unit. The tapes most commonly used are punched paper

or plastic tapes in which the position and number of holes on each line or row across the tape (see illustration) take the place of the desired numeral, letter or special command. If these types of tapes are used, this activity is done with an electric typewriter, a tape punching unit, and a tape reading unit.

The machine tools used in numerical control have been specifically designed for numerical control although standard modified machines (retrofits) have been used. These machines have a great range of speeds, feeds, etc. and are controlled by a machine control unit mounted on the machine or on the floor next to it. The tape prepared by the tape preparation unit is inserted in the machine control unit which then translates the information on the tape into machine movements along rectangular or Cartesian coordinate axes producing the part.



Electronic Industries Association Standard 1-Inch Perforated Tape—Configuration of Perforations and their Significance

Nusite. A term applied to a method of hardening high-speed steel which results in a hardness of 65-66 Rockwell C., combined with about twice the normal toughness. Tools hardened by the Nusite method, as compared with tools hardened by ordinary

methods, are claimed to permit one or more of the following, depending upon the job: Increased cuts, increased feeds, longer runs between grinds, cutting of tougher steels, making of intermittent cuts, reduction of chipping and breakage, and usually some increase in speed. This method is intended to provide tools which fill a gap between high-speed tools hardened in the ordinary way and the carbide tools.

Nut Standardization. The American Standard for Nuts includes a Regular Series and a Heavy Series. Regular nuts are for general use and the heavy nuts are for applications requiring a larger bearing surface. In each of these series, there are unfinished, semi-finished, and finished grades.

Regular Nuts, Unfinished: The width across the flats of square and hexagon nuts equals $1\frac{1}{2} \times$ screw thread diameter, excepting ¼- to ⅝-inch sizes inclusive, which have widths equal to $1\frac{1}{2} \times$ screw thread diameter + 1/16 inch, adjusted in all cases to sixteenths. Unfinished nuts are threaded but not machined on any other surface.

Regular Nuts, Semi-Finished: The width across the flats (hexagon nuts only) equals $1\frac{1}{2} \times$ screw thread diameter, excepting sizes ¼ to ⅝ inch inclusive, which have widths equal to $1\frac{1}{2} \times$ screw thread diameter + 1/16 inch, adjusted in all cases to sixteenths. Semi-finished nuts are threaded and machined on bearing surface only.

Regular Nuts, Finished: The width across the flats equals $1\frac{1}{2} \times$ screw thread diameter, excepting ¼- to ⅝-inch sizes inclusive, which have widths equal to $1\frac{1}{2} \times$ screw thread diameter + 1/16 inch, adjusted in all cases to sixteenths. Finished nuts are threaded and finished on all surfaces. Made in hexagon form only.

Heavy Nuts, Unfinished: The width across the flats of square and hexagon nuts equals $1\frac{1}{2} \times$ screw thread diameter + ⅛ inch, adjusted to sixteenths excepting sizes below ½ inch.

Heavy Nuts, Semi-Finished: The width across the flats (hexagon nuts only) equals $1\frac{1}{2} \times$ screw thread diameter + ⅛ inch, adjusted to sixteenths, excepting sizes below ½ inch.

Heavy Nuts, Finished: The width across the flats equals $1\frac{1}{2} \times$ screw thread diameter + ⅛ inch, adjusted to sixteenths, excepting sizes below ½ inch. Made in hexagon form only.

This standard was adopted by the American Standards Association in 1933.

Nut Taps. A tap designed for the use of machine shops which tap their own nuts, generally from blanks supplied by a nut manufacturer. It is customary practice to give the entering threads for approximately 75 per cent of the thread length a slight taper

in both pitch diameter and root diameter to insure tapping a nut with a full form of thread. The length overall, length of thread, and length of shank are appreciably longer than on a regular (standard) hand tap.

Straight Shank Tapper Taps: A tap used by nut manufacturers in tapping nuts in vertical spindle machines. They are made 12 or 15 inches long and the nuts are allowed to accumulate on the shank during the tapping operation. Shanks are machined to fit the various spindles in ordinary use. Made in both fractional and machine screw sizes.

Bent Shank Tapper Taps: A tap designed for use in an automatic tapping machine. The nuts are fed to the tap by means of a hopper, and there is a continual production of tapped product without stopping or reversing. Made in both fractional and machine screw sizes.

Nuttall Stub-Tooth Gears. See Stub-tooth Gears.

Nut-Tapping Machines. Some of the most highly developed and ingenious tapping machines are used for tapping nuts. These machines are made in reversing and non-reversing types and may be hand-operated, semi-automatic, or fully automatic. Reversible machines are used for tapping nuts having closed ends which make it necessary to reverse the tap and back it out. The non-reversible machines may be so arranged that the nuts pass onto a long tap shank from which they are removed periodically, or the tap, on a machine of the automatic type, may be so held and driven that the tapped nuts pass over it completely without removing it or stopping the machine.

Automatic Machine of Bent-Tap Type: One type of automatic machine is equipped with a tap having a shank that is bent on a rather large radius so that the extreme end is at right angles to the main tap body. This shank with the right-angle bend is held in a groove in the spindle large enough to allow the nuts to slide over the shank. When the machine is in operation, the tapped nuts are forced along the shank around the curved end and ejected from an opening in the side of the spindle. The reason for using a bent tap is that the curved shank makes it possible to drive the tap and at the same time have it sufficiently free in the spindle opening to allow the nuts to pass over the shank and be ejected at the end; consequently, the machine can be operated continuously and without reversing the spindle or removing the tap for unloading the tapped nuts.

Automatic Machine of Straight-Tap Type: Another type of automatic machine has a stationary straight-shank tap and a mechanical device employed to grip and revolve the nut blank while advancing it over the stationary tap at the linear speed required

by the lead of the tap threads. In operation, the nut blanks fall from a hopper down a chute which delivers them into line with and facing the tap directly in back of a revolving head. They are then pushed automatically through this head and into a driving jaw within the head. Each nut is held square with the tap and is screwed on it as the head revolves. A three-fingered jaw is required for hexagonal nuts, and a four-fingered jaw for square nuts. The tap shank is of sufficient length to accommodate two pairs of mechanically operated clamps, by means of which the tap is held stationary. These clamps are engaged and released alternately to permit the tapped nuts which accumulate on the tap shank to be carried toward the end of the shank, from which they drop off and slide into a receptacle.

O

Oakum. Oakum is used for calking seams of ships, stopping leaks, and by plumbers in the packing of joints such as the bell-and-spigot and Matheson types. Oakum may be made by untwisting tarry ropes and picking them into loose fiber. That made from untarred ropes is called "white oakum." In making a calked joint of the bell-and-spigot type, the oakum is forced into the joint with a yarning iron, and firmly calked with a calking tool; then molten lead is poured on top. The oakum should fill the bell of the joint to within about one inch of the top, because the really beneficial expansion of the lead, due to blows on the calking tool, is effective only through a comparatively small depth of lead. Additional metal is of no real value, merely filling space which the oakum might fill at less expense.

Obtuse Angle. An angle larger than 90 degrees. See Angle.

Octahedral Borax. This is a form of borax suitable for use as a flux in soldering or welding. It is also known as jeweler's borax.

Octane Number of Motor Fuels. The property of a motor fuel such as gasoline in regard to detonation is very important. Detonation, or "knocking" as it is commonly called, is indicated by a pronounced metallic blow which is similar to the noise produced by some mechanical cause such as looseness or play between parts. Actually, however, detonation or knocking in automobile or similar motors, when caused by the fuel used, is due to vibrations set by a local high pressure which is similar in its effect to a hammer blow. Detonation should not be confused with pre-ignition. The term pre-ignition relates to ignition that occurs before the spark has passed. This may be due to overheated spark-plug points or scraps of stray incandescent carbon. While such pre-ignition is likely to cause violent thumping, detonation or knocking occurs after ignition by the spark; in other words, detonation follows the spark while pre-ignition precedes it.

Cause of Detonation: When there is no detonation, combustion started by the spark spreads steadily throughout the combustion space. In using a detonating fuel, self-ignition may occur and the last portions of the charge may burn almost instantaneously. When this occurs, a detonation wave is caused and the gas pressure rises locally to a point far in excess of the average pressure. In fact, this detonation wave may deliver a blow of sufficient intensity to break the piston. The characteristic

knock caused by some fuels occurs when this detonation wave reaches the cylinder wall. The almost instantaneous combustion which causes the pressure wave is confined to the last part of the charge. Whether such detonation or knocking occurs, depends upon the chemical characteristics of the fuel, the initial temperature and pressure, and the rate of combustion of that part of the fuel which is first ignited. Since the action of gasoline in regard to detonation is a very important characteristic, the relative qualities of different fuels should take this property into account.

Establishing Octane Number: The action of a fuel in regard to detonation might be established in terms of the highest useful compression ratio values. In other words, such values might be used to range fuels according to a certain order of merit. However, a compression ratio to avoid detonation depends very much upon the speed as well as various other factors; consequently, it is important to classify fuels in regard to detonation by some method which does not relate only to a particular engine. Thus, the scale of detonation should be independent of any particular engine. Such a scale has been adopted in terms of two hydrocarbons. One of these, iso-octane, is very good in regard to detonation, and the other, normal heptane, is very bad.

The knock or detonating characteristics of a fuel such as gasoline, is determined by comparing it under standard test conditions with whatever proportions of octane and normal heptane just match its anti-knock quality. For example, if a gasoline is matched by a mixture of 75 parts octane and 25 parts heptane, its octane number is 75. In other words, octane number is defined by and is numerically equal to the percentage by volume of iso-octane (2,2,4-trimethylpentane) in a mixture of iso-octane and normal heptane, used as a primary standard for measurement of knock characteristics. Thus, by definition, normal heptane has an octane number of zero and iso-octane of 100.

C.F.R. Engine: The engine used in establishing the octane number is known as the C.F.R. engine. This abbreviation is from the name Cooperative Fuel Research Committee, composed of representatives of the American Petroleum Institute, Automobile Manufacturers Association, Society of Automotive Engineers and U. S. Bureau of Standards. This engine has a continuously variable compression and apparatus for determining the knock intensity. The iso-octane and normal heptane referred to is the primary reference fuel. To insure a greater degree of reproducibility in testing, it is preferable to use secondary reference fuels which have been properly calibrated against the primary reference fuels. Such secondary reference fuels may be straight-run or other stable gasolines suitable for the purpose. One of the reference fuels should be of low knock rating and the other

of high knock rating. These secondary reference fuels are calibrated against normal heptane and iso-octane, and the calibration is expressed in terms of the octane-number scale.

The octane number of a fuel is ascertained by comparing the knock intensity for the fuel with those for various blends of the reference fuels until two blends differing in knock rating by not more than two octane numbers are found, one of which gives a higher knock intensity than the fuel and the other a lower knock intensity. Before the test sample and the blends of the reference fuels can be compared, the compression ratio must be set to give the proper knock intensity and the carburetor adjusted to give the maximum knock for each fuel. With the carburetor set for the air-fuel ratio of maximum knock, alternate series of readings of knock intensity are taken on the fuel under test and on a reference fuel blend.

Advantages of High-octane Fuels: Modern gasolines having high octane ratings permit higher compressions without knocking or "ping" as it is sometimes called. These high-octane fuels may be used primarily either to increase power or fuel economy, or to secure a combination of these two advantages. The maximum gain in power may be obtained by supercharging to the limit of the fuel as is done in connection with aircraft. The highest gains in economy are obtained by increasing the compression ratio as much as possible with a given fuel without excessive knocking.

Octoid Gear Teeth. An octoid bevel gear tooth is formed when planing bevel gears on the Bilgram, Gleason, or other similar type of generating machines. In these machines, the teeth of the gears are shaped by a tool which represents the side of the tooth of an imaginary crown gear. The cutting edge of the tool is a straight line, since the imaginary crown gear has teeth the sides of which are plane surfaces. Theoretically, however, the sides of the teeth of a true involute crown gear are slightly curved: hence, the tooth formed by the generating machine is not an involute gear tooth, but has been called *octoid* by Geo. B. Grant. This form was invented by Mr. Bilgram. Both the octoid and the involute tooth give theoretically correct action.

Odd-Leg Caliper. This is a caliper in which the points of both legs are bent in the same direction. A caliper of this type is used for measuring the distances between shoulders, and for similar work.

Odometer. An odometer is an instrument that is attached to the wheel of a vehicle for measuring the distance traveled by the vehicle, by recording the number of revolutions that the wheel makes in traversing the distance. When the circumference of

the wheel is known, the approximate distance can be calculated. The instrument is used in engineering for preliminary surveying. In this case, the wheel to which the odometer is attached is generally made with a circumference of 10 feet. Maps are frequently prepared by the use of an odometer for measuring distance, the compass determining directions.

Odontograph. An odontograph, in the limited sense of the word, is an instrument for laying out the forms of gear teeth, or a guide used in cutting gears to a given form in a gear-cutting machine. The term is, however, also applied to any method or table for laying out gear teeth by means of circular arcs which closely approximate the exact tooth curves. The most generally known, as well as the most accurate, of these odontographs is the one devised by George B. Grant. This odontograph consists of diagrams and tables giving the radii and location of the centers for arcs that approximate the true gear-tooth shape. These tables are found in engineering handbooks.

Odontometer. The "odontometer" is a simple instrument or gage for testing the accuracy or uniformity of gear tooth profiles and spacings of the teeth in production work. It is equally adaptable to spur and helical gears and is self-contained. In general, the instrument is used as a comparator, to test the uniformity of interchangeable and mating gears. If actual measurements are required, the distance between the two parallel working faces of the instrument can be measured. The instrument is made so that a dial indicator is in full view of the operator as he rocks it over the teeth. Adjustment from one pitch to another can be made quickly.

O. D. Pipe. This is an abbreviation applied to large wrought or steel pipe, the nominal size of which is designated by the outside diameter instead of the inside diameter as in the case of smaller sizes. According to the American Standard, all sizes above 12 inches represent the nominal outside diameter. These "O. D. pipe" range from 14 to 24 inches.

Oersted. The oersted is the unit of magnetizing force (magnetic intensity) in the cgs electromagnetic system and is equal to the intensity of a magnetic field at any point in a vacuum in which a unit magnet pole experiences a force of 1 dyne.

Some confusion may result if it is not realized that (1) the oersted was formerly a unit of magnetic reluctance, and (2) the unit of magnetic field intensity used to be called the *gauss*. The change to the present usage was made by the International Electrical Committee in 1930.

Ogee Cam Curve. See Harmonic Motion Curve.

Ohm. The unit of resistance to the flow of an electric current is known as an *ohm*. A conductor is said to have a resistance of one ohm if the ratio of a constant electromotive force, applied at its ends, in volts to an unvarying current, flowing through it, in amperes is equal to unity. According to the International Standard, it is equal to the resistance offered to an unvarying electrical current by a column of mercury having a mass of 14.4521 grams at 0 degrees C. (32 degrees F.), the column to be of constant cross-sectional area and to have a length of 106.300 centimeters (41.850 inches).

Ohm's Law. The electric current that flows through a circuit is directly proportional to the electromotive force of the circuit and inversely proportional to the resistance in the circuit. This relation is known as Ohm's Law, and may be expressed in formulas as follows:

$$I = \frac{E}{R}; \qquad E = IR; \qquad R = \frac{E}{I};$$

in which, I = current in amperes; E = electromotive force in volts; R = resistance in ohms.

Oil, Acid Number. See Acid Number of Oil.

Oil and Chip Separators. See Chip and Oil Separators.

Oil and Gas Engines. See Internal Combustion Engines.

Oil Bath Lubrication. Oil bath or submerged lubrication, which consists in running parts in a bath of oil which they continually stir up and spread over themselves, exists in many forms. In the oil bath as correctly arranged, there is never any lack of lubricant and the chief care is to see that no sediment is thrown up, or that any parts are shielded from the spread of oil.

Oil Bonding Process. With the oil bonding process for grinding wheels, an oxidizing oil is mixed with the abrasive grains. After this mixture has thickened from exposure to the air, it is formed into wheels, by compressing it into molds by means of hydraulic presses. The molded wheels are then baked slowly at a low temperature. Oil wheels are similar in action to elastic wheels, but less dependable as to grade and uniformity.

Oil-Burning Furnaces. The use of oil in furnaces for the heat-treatment of steel possesses, in many cases, certain advantages over other methods of heating. Chief among these advantages is the consideration of economy, as oil in the past, at least, has generally been cheaper to use than any other available form of fuel. The factor of economy is limited, however, by a somewhat increased complication in the method of operation,

and, on this account, oil is not recommended for furnaces that will operate on gas with a consumption of 230 cubic feet per hour or less. The best results with oil-heated furnaces are secured with the larger-sized units. In those cases where the oil is atomized by steam, it is necessary to supply a certain amount of additional air in order to obtain the desired combustion. Steam is a chemical compound consisting of two parts of hydrogen and one part of oxygen and when the steam impinges upon the white hot brickwork of the furnace, the chemical union is broken, hydrogen and oxygen being liberated. The oxygen set free in this way is used in effecting the combustion of the oil, and the hydrogen is carried into the furnace. As hydrogen itself is a combustible gas, and is burned in the furnace by the oxygen of the additional air which is supplied for this purpose, this combustion of hydrogen takes place further from the burner than the point at which the bulk of the oil is burned, and helps considerably in maintaining a uniform temperature. When the oil is atomized by a stream of compressed air, there is no hydrogen present to be burned in the furnace. Crude oil and kerosene are commonly used in oil-heated furnaces. To insure an unvarying temperature, the air and fuel pressures should be uniform. The two general types of oil-fired furnaces used are the over-fired type and the under-fired type.

Oil, Cold Test. See Cold Test of Oil.

Oil Coolers. A properly designed oil cooler will extract the greater part of the heat absorbed by oil from bearings and return the oil to the bearings at a comparatively low temperature. Cooling the oil permits it to absorb a greater amount of heat from the bearings, thus lowering the bearing temperature and at the same time decreasing the rate of evaporation. If the temperature is carried too low the increased viscosity of the oil will cause a slightly higher bearing friction and retard the rate of separation of water and other foreign matter.

The efficiency of the oil cooler depends upon the initial temperatures of the oil and water, the amount and rate of oil and water circulated, the mechanical design of the oil cooler and the cleanliness of the surfaces of the coils. The rate of heat absorption in the cooler depends largely upon the rate of flow of the oil film near to the metal surfaces. This rate of flow is again dependent upon the viscosity of the oil, all of which means that high viscosity oils require a much larger cooling surface than more fluid products for the same temperature reduction.

Oildag. See Graphite.

Oil Extractors. The oil that flows onto the cutting tools of automatic turning machines and other classes of machine tools,

may be extracted from the metal chips or other foreign matter by means of an oil extractor or separator. The common design of separator intended for use in machine shops for recovering oil from chips is of the centrifugal type and is driven either by belt or by a direct-connected motor. See Chip and Oil Separator.

Oil-Filled Cable. An oil-filled cable is a cable having insulation impregnated with an oil which is fluid at all operating temperatures, and provided with facilities such as longitudinal ducts or channels and with reservoirs, or their equivalent, by means of which positive oil pressure can be maintained within a cable at all times, incipient voids promptly filled during periods of contraction and all surplus oil adequately taken care of during periods of expansion.

Oil Fire Point. See Fire Point of Oil.

Oil Flash Point. See Flash Point of Oil.

Oil Grinding. Oil grinding is the final grinding to which steel balls are subjected in their manufacture, and by means of which the balls are brought to exact size. The oil-grinding operation is practically a lapping process; no grinding wheel is used but the machine has two plates, one of which is grooved, between which the balls roll. The grinding is done with fine abrasive and oil.

Oil-Grooves in Bearings. With the exception of small solid bearings subjected to light loads, it is common practice to groove bearings in order to distribute the lubricant more uniformly. Such grooves should not extend across that part of the bearing surface likely to be subjected to oil-film pressure because grooves in the pressure area permit the oil to follow the path of least resistance, thus preventing, partially, the formation of an oil film on the load-carrying side. Grooves should never be cut into the journal, but always in the surrounding bearing. A longitudinal groove along the top is often used but one inclining from the oil hole in the direction of journal rotation is preferable. This groove should not extend to the ends of the bearing, unless the bearing is ring-oiled or chain-oiled, and leakage at the ends drains to the housing well for recirculation. With two-part bearings, the longitudinal grooves may be formed along each side merely by chamfering the edges of the cap and base but not the entire length. The edges of all chamfers and grooves should be rounded to avoid sharp corners and facilitate the introduction of the oil between the journal and the bearing metal.

Point of Oil Entry: The locating of maximum oil-film pressure depends upon the speed, load, direction of rotation, and other factors. If the load is applied to a horizontal journal running counter-clockwise, the center of maximum pressure will be located

to the right of the foot of the vertical center-line anywhere from, say, 10 to 45 degrees, depending upon the load, speed, etc. Excessive load or very low speed may shift the center of maximum pressure practically to the bottom of the bearing circle. The minimum pressure area for counter-clockwise rotation will be at the upper part of the bearing somewhere to the right of the vertical center-line. Reversal of rotation will shift these points of maximum and minimum pressures to the same relative positions to the left of the vertical center-line.

For gravity feed, the oil should enter on the low-pressure side; and if the journal is carrying the load, a point of entry at the top of the bearing will meet practical requirements. For pressure systems, the oil should enter adjacent to the high-pressure area on the *in-feeding* side toward which the journal surface is moving. If the point of entry is on the horizontal center-line (or below it not over 45 degrees) at the left-hand side for counter-clockwise rotation and at the right-hand side for clockwise rotation, the oil will enter on the in-feeding side.

Oil-Hole Drills. In drilling rather deep holes, it may be difficult to supply the point of the drill with the required amount of oil or cutting compound due to the tendency of the chips to carry the fluid back with them before it reaches the bottom of the hole. To overcome this difficulty, oil-hole drills may be used. This type is provided with internal holes or ducts through which the cutting fluid can be carried right to the drill point. The fluid and chips escape through the flutes of the drill in the usual manner.

Oiling, Ring Method. See Ring Oiling.

Oiling Systems. See Lubricating Systems.

Oilless Bearings. Oilless or self-lubricating bearings are especially adapted for applications in places where oiling is undesirable, or where the bearings are difficult of access, or likely to be neglected. They are of particular value in such plants as canneries, textile mills, etc., where the product is liable to harm from dripping oil, and oilless bearings are applied in many other classes of service. A number of different types of oilless bearings have been developed, each of which doubtless has its advantages when applied under suitable conditions. One type consists of wood impregnated with wax, oil or paraffin; another is made of bronze and has graphite inserts; another type is formed of graphite impregnated with some bearing metal such as a white alloy or bronze; and still another consists of hard maple reinforced by babbitt metal, the wood shell of which is impregnated with lubricants and thus serves as an oil reservoir.

Another group of oilless bearings are porous bearings. These are usually of plain or leaded bronze, sometimes of iron, stain-

less steel and more rarely, aluminum and are made from powdered metal that has been pressed into the desired shape and then sintered, producing a sponge-like structure capable of absorbing fairly large quantities of oil, usually about 25 per cent of the volume of the bearing material. These bearings are used where lubrication supply is difficult, inadequate, or infrequent. This type of bearing should be flooded from time to time to resaturate the metal. In bearings of these materials the allowable rubbing speed may range up to 2000 fpm with very light loads. The usual operating speed range would be, however, from 75 to 1500 fpm. For porous bearings impregnated with oil the maximum operating temperature is about 150 degrees F. Tests have shown that applied loads should be steady and unidirectional and clearances between shaft and bearing should be between 0.0007 and 0.0012 inches. These materials are generally employed as bushings rather than in split shell bearings.

Oil of Vitriol. This is a name sometimes used for sulphuric acid.

Oil Quenching Baths. See Quenching Baths, Oil.

Oil-Ring Design. See under Ring Oiling.

Oil Shale. There are large deposits of oil shales in the western and southern parts of the United States, Colorado alone, according to an estimate, having enough oil shales to produce 20,000,000,000 barrels of oil and 300,000,000 tons of ammonium sulphate. The oil shale industry originated in England in 1694 but the chief commercial operations are in Scotland. One ton of shale yields from 1 gallon to 90 gallons of oil. In Scotland the average is about 23 gallons per ton. Gasoline obtained from shale oil contains large amounts of olefins and aromatic compounds and is inferior in quality as compared with gasoline obtained from petroleum.

Oils, Slushing. See Slushing Oils.

Oils, Soluble Cutting. See Soluble Oils for Cutting Tools.

Oil Stains on Concrete. Oil stains on concrete floors may be removed by covering with a mixture of 1 pound of oxalic acid, 3 gallons of water and enough wheat flour to make a paste that can be applied with a brush. The paste is removed with clean water.

Oilstones. The natural oilstones commonly used are the *Washita* and *Arkansas*. The Washita is a coarser and more

rapidly cutting stone than the Arkansas, and is generally considered the most satisfactory for sharpening woodworkers' tools. There are various grades of Washita rock, varying from the perfect crystallized and porous whetstone grit, to vitreous flint and hard sandstone. The sharpness of the grit of any Washita stone depends entirely upon the character of its crystallization. The best whetstones are porous and uniform in texture and are composed entirely of silica crystals. The poorer grades are less porous, making them vitreous or "glassy." They may also have hard spots or sand holes, or contain grains of sand among the crystals. For general work, a soft, free-grit, quick-cutting stone is required, although a fine-grit medium-hard stone is sometimes preferable. Washita stones are sometimes white in color, but frequently streaked more or less with a yellow or red tinge. They are found in the spurs of the Ozark mountains of Arkansas. Many artificial oilstones are now used for various classes of work. These are commonly furnished in three grits: viz., fine, medium, and coarse, and in all required shapes.

Oil Switches. See Switches, Oil Type.

Oil Viscosity. See Viscosity of Oil.

Oldham's Coupling. Oldham's coupling may be used when two shafts to be connected are parallel, but slightly out of line. In this coupling each shaft end has a flanged hub attached to it, these flanges being keyed firmly to their respective shafts. Across the face of each of these flanges, a single groove, passing through the center, is planed, and between the ends of the flanges is interposed an intermediate disk which has a tongue on each side running diametrically across its face, these tongues engaging with the plain grooves in the faces of the flanges. The tongues in the intermediate disk are placed at right angles to each other; hence, when the shafts rotate, the motion can be transmitted from one shaft to the other at a uniform rate, although the axes of the two shafts are not in alignment.

"Old Man." An "old man" is the supporting bracket for the feed screw end of a ratchet drill. It consists of an L-shaped member which is usually bolted, or clamped to the part being drilled, and an adjustable arm against which the pointed end of the ratchet feed-screw bears. This device is also used with pneumatic and electric portable drills to provide "backing" or a resisting support for the drill.

Olympic Bronze. High-strength copper alloy containing silicon and zinc. Available in three types: Type A—plates, sheets, strips, rods, wire, tubing, forgings, and welding rod; Type B—free-turning wire and rod; Type C—ingots for casting purposes

and sand castings. Tensile strength from 40,000 to 150,000 pounds per square inch, the lower figure applying to Type C castings and the higher to Type A wire. Suitable for all purposes where high-strength, corrosion-resistant machine parts, forgings, or castings are required.

Open-Circuit Cell. This is a primary cell which will only supply current intermittently and then only for a short period of time, but which will stand on an open circuit for a long time without loss of materials through electrolytic action. Most dry cells are of this general type.

Open-Hearth Process. The open-hearth process, sometimes called "the Siemens-Martin process," is a method of producing steel by mixing pig iron with steel and iron scrap and removing the impurities contained in the bath of iron on the hearth of a regenerative furnace, the hearth being open or exposed to the action of the flame. The process is similar to the puddling process, but is carried out on a much larger scale. The gas and the air are heated to a high temperature (over 1000 degrees) before entering the combustion chamber, by passing through regenerative chambers. Owing to this preheating of the gas and air, a very high temperature can be maintained in the furnace so as to keep the iron liquid. The charge of molten metal has added to it a certain proportion of ore, iron scale or other oxides, the chemical reaction of which keeps the molten iron in a state of agitation. The process may be carried out by either the basic or the acid method. In the *basic*, or dephosphorizing, furnace, the slag is basic and the furnace lining is neutral, but burnt lime is added to the charge to remove the phosphorus. In the *acid*, or undephosphorizing, process, there is a silicious slag and the furnace has a silicious lining, with the exception that the bottom lining of the furnace for both acid and basic processes is practically the same. The acid is the faster process, as the heat-insulating layer is comparatively thin; it is also the cheaper process, but this difference in cost is offset by the greater cost of pig iron and scrap free enough from phosphorus. The open-hearth process produces a more uniform and reliable steel and a greater yield of ingots from the metal charge than does the Bessemer process; and the operations are under greater control and samples can be frequently taken. Most of the structural steel used is made by the open-hearth process.

Open-hearth Furnace: The furnaces for the open-hearth process of making steel are of various designs. Some are stationary, although many are arranged so that they can discharge their steel by being tilted, while others can be entirely removed from their setting and poured. They vary in size from 5 to 15 tons, for

special grades of steel, and from 50 to 80 tons and upward, for standard grades; furnace units of from 50 to 60 tons are now generally preferred. The furnaces may be heated by natural gas, producer gas, or oil. The furnaces consist of a rectangular hearth with ports at each end through which the gas enters and leaves. Two chambers at each end provide means for heating the air and the gas. The roof of the furnace must be high enough so that it will not be burned by an impinging flame from the ports. The hearth must be of such a length that there will be complete combustion; its length should be about two or two and one-half times its width; its depth should be sufficient to permit the oxidation of the metal, yet it should be sufficiently shallow to promote thorough heating, and reasonably quick working of the bath. Usually the maximum width of the hearth is about 15 feet, while the depth is about from 15 to 20 inches.

Open-Hearth Steel. As defined by the International Association for Testing Materials, open-hearth steel is any steel made by the open-hearth process, irrespective of the carbon content. As a rule, however, open-hearth steel contains a smaller percentage of carbon than the steel generally known as *crucible* or *tool* steel.

Open-Hearth Tool Steel. A large percentage of the steel used for making tools, if all classes of tools are considered, is produced by the open-hearth process. Open-hearth tool steel, however, is not recommended ordinarily for metal-cutting tools; in fact, either crucible or electric tool steel is specified by practically all manufacturers whenever the use of a dependable high-carbon steel of the best quality is considered essential.

Open-hearth tool steel meets all requirements for a large variety of tools and implements which ordinarily are made from steels containing about 0.65 to 0.85 per cent carbon. These tools include hammers, sledges, pliers, woodworking tools, stone cutters' tools, picks, bars, axes, cheap knives, blacksmith tools, forging dies, agricultural implements, and numerous other products. The extensive use of open-hearth steel in the agricultural field accounts for the name "agricultural tool steel."

In attempting to make a direct comparison between steels made by the open-hearth process and either the crucible or electric process, it should be remembered that much depends upon the selection of raw materials and the care with which each process is conducted. Considering these steels as they are produced under ordinary commercial conditions, it is the general opinion of manufacturers that either crucible or electric steel is superior to open-hearth steel except for the general classes of tools men-

tioned, which are made from the relatively cheap open-hearth steel, as the latter meets all practical requirements.

Open-Sand Castings. Rough castings, such as foundry plates, gaggers, etc., are usually made without a cope or other covering. Castings made in this way are known as *open-sand* castings. In preparing molds that are to be cast in this way, it is essential that they be level, as there is nothing to confine the metal which "seeks its level."

Open Tailstock. This is a special design of tailstock for bench lathes in which the upper part of the spindle bearing is removed, so that the tailstock spindle may be readily lifted out of place. It is used on light delicate work which requires different tools to be employed. The open construction facilitates the rapid replacement of the spindle which holds the tool.

Optical Comparator Gages. Intricate forms such as non-standard screw threads and complicated form tools can readily be checked as to accuracy, form, and size by an instrument known as an optical comparator. A light beam is thrown on the part and, by means of a system of lenses, a shadow cast by the outline of the part is magnified many times and projected on a ground-glass screen. The desired size and shape of the part is drawn very carefully in pencil on the ground glass 25 to 100 times normal size, according to the magnification used in the optical system. On this enlarged scale, deviations in size as small as ten-thousandths of an inch can readily be measured. In other cases the work may be held between centers or in a special fixture, and in somewhat different cases the light may be reflected from the work to show an enlarged picture rather than a shadow. This latter set-up is often used to examine a complete operating watch or similar mechanism.

Optical Flats. Optical flats are glass disks made of a special brand of glass, whose surfaces are the nearest possible approach to perfect planes. Optical flats provide a simple and rapid means for checking surfaces that have been made very accurate by careful lapping. In testing such surfaces, all dirt or dust is first removed from both the glass and the work; then the optical flat is wrung on the work sidewise, with a slight pressure. If the lapped surface is sufficiently accurate, rainbow colored bands caused by the interference of light waves become visible across the working face of the optical flat. Ordinarily, lapped surfaces are passed as satisfactory if these interference bands are visible, but for exceptionally accurate work, the nature or formation of the bands is considered. Thus if a surface is perfectly flat, the bands extend across it in straight parallel rows, whereas the slightest amount of concavity or convexity would cause more or

less curvature or irregularity of the bands. Optical flats intended for general testing of plane surfaces, as made by one manufacturer are 1¾ inches in diameter. One grade is guaranteed to be accurate within limits of 0.000004 inch and another grade to 0.000008 inch. See also Light-wave Measuring Method.

Optical Measuring Tools. Fixed gages and measuring devices of the purely mechanical type are used largely throughout the machine-building field, but optical methods are being applied on an increasing scale in connection with certain classes of measuring or checking operations incident to the manufacture or inspection of interchangeable parts, tools, etc. These optical devices for shop use are mostly of simple design and are not to be confused with scientific apparatus such, for example, as the interferometer, but nevertheless the extreme accuracy of some of the finely graduated glass scales, as well as the prisms and lenses used in these optical instruments for shop and tool-room use, depends directly upon the more highly developed forms of optical apparatus. In the design of these tools, optical principles and methods have been utilized in different ways. Most of the instruments are provided with finely graduated scales and "spider" or "hair" lines on glass, in conjunction with means of magnifying the graduations so that readings or other observations may be readily made. The reasons for employing these optical appliances in preference to purely mechanical devices vary somewhat with different instruments, but, in general, the plan is to safeguard against errors that might otherwise result, either from wear, temperature changes, mistakes in checking readings, or variations due to the "feel" or pressure of contact between instrument and work. Some of these optical measuring tools are arranged for general use, and others are designed expressly for one class of work.

Optimeter. An "optimeter" may be described briefly as an optical indicator or comparator, which utilizes a microscope for magnifying the image of an exceedingly accurate glass scale which, through suitable reflecting means, enables the observer to obtain by direct reading the difference between the measurement of whatever gage or other part is being tested and the precision gage-block or other standard used in setting the optimeter to the zero position.

Ordinate. In analytical geometry, the ordinate of a point is, generally, that coordinate which is measured parallel to the vertical axis. In mathematical expressions, the ordinate of a point is generally designated by the letter y. Whether the coordinate axes are parallel to each other or not, the ordinate is always

measured along a line parallel to the vertical axis, and not along a line at right angles to the other axis. See also Abscissa.

Ore. An ore is a material that contains a metal in such quantities that it may be mined and worked commercially for that metal. In an ore, the metal usually is contained in chemical combination with some other element, and, in addition, there are generally various impurities; hence, the condition in which the metal exists in the ore differs greatly. In all commercial iron ores, the metal occurs as an oxide, a carbonate, or a sulphide. The ore may be deposited in beds, lenses, or veins. *Beds* are masses of minerals found in solid strata; *lenses* or *pods* are irregular masses of ore imbedded in, and separated by, earth or rock; veins fill crevices or seams and generally have quite well-defined walls. Ores having a high metal content are termed "rich"; those having a low metal content are termed "lean."

Commercial iron ore—oxide, carbonate, or sulphide of iron—contains from about 35 to 70 per cent of iron, together with impurities of phosphorus, silica (sand), etc. When ore contains less than 40 per cent of iron, it must first be concentrated, and when it contains less than 25 per cent of iron, it is not considered of any commercial value, because the cost of extracting the iron from the ore is too high to make it possible to sell the product in competition with that extracted from richer ores. The best iron ores are those in which the iron is combined with oxygen, forming an oxide ore. Ores which consist of carbonates, that is, minerals in which the iron is present in combination with carbon and oxygen, are also mined, and are of considerable importance, although they must be roasted to drive off the carbonic acid. The sulphide ores, that is, minerals in which the iron is present in combination with sulphur, are also used, but are of minor importance. These ores must be desulphurized in order to eliminate the sulphur. In fact, all iron ores, whether sulphides or otherwise, which contain sulphur to an amount exceeding one per cent, must be subjected to a special treatment before smelting. The three most important iron ores consisting of iron oxides are *magnetite*, *hematite*, and *limonite*. The carbonate iron ore is known as *siderite* and the sulphide iron ore as *pyrite*.

Organic Chemistry. In general, organic chemistry is the chemistry of carbon compounds. Some carbon compounds, however, such as carbon monoxide, carbon dioxide, carbon disulphide, and silicon and iron carbides, are considered as inorganic substances and some other substances which do not contain carbon, are treated as organic.

Orifice Method. This is a method of testing air compressors based upon the principle that if gas is allowed to pass from one

vessel in which the pressure is high, through a small opening into a vessel where the pressure is low, the volume of gas passing through the opening in one minute is constant as long as the pressures are unchanged. This principle has been thoroughly investigated, and is used as the basis of many methods of measuring both gases and liquids. In the orifice method, the volume of air actually passing through the orifice is measured.

Origin. In analytical geometry, the origin is the point where the coordinate axes intersect.

Orthographic Projection. See Projection.

Oscillating Current. See Periodic Current.

Oscillograph. In order to observe and measure the rapid variations of current and voltage which regularly occur in alternating-current circuits and as transient phenomena in both alternating- and direct-current circuits, an instrument called an oscillograph is utilized. By means of such an instrument, the variations are plotted on a suitable screen or recorded on a photographic film.

The two chief types are the moving coil oscillograph which is used for frequencies up to 2000 cycles per second, and the cathode ray oscillograph which is used chiefly for frequencies beyond this range.

Oscilloscope. An oscilloscope is an optical-mechanical apparatus by means of which it is possible to observe the action of high-speed mechanisms under actual working conditions. With this device, the action of the mechanism, moving at high speed, may be studied as if it were moving very slowly or actually standing still. This is accomplished by the use of a special type of electrical lamp, the flashes of which are synchronized with the movements of the revolving mechanism. If the lamp flashes illuminate the moving part repeatedly at the same point in its travel, that point will appear stationary, because it is illuminated only at the instant when it passes a given position. If the successive flashes of the lamp illuminate the moving part at points slightly in advance of each other, the part will have the appearance of moving slowly. See also Vibroscope.

Osmondite. Osmondite is the constituent obtained in steel that has been drawn, after hardening, to a temperature of about 750 degrees F. This condition marks the boundary line between troostite and sorbite, troostite being developed by a lower drawing temperature, and sorbite, by a higher temperature.

Ostwald Calorie. The calorie or metric heat unit generally used in engineering is the kilogram-calorie, also known as kilo-

calorie or large calorie, which is equivalent to the heat required for raising the temperature of one kilogram of water one degree C. In electro-chemistry, a unit known as the *Ostwald calorie* is frequently used. This is equivalent to the amount of heat required for raising the temperature of one gram of water from 0 to 100 degrees C. One kilogram-calorie equals 10 Ostwald calories.

Otto Cycle. See Cycles, Internal Combustion Engines.

Ounce Metal. This is an alloy widely used for pump bodies, valves, and similar parts. It is composed of 85 per cent of copper, 5 per cent of tin, 5 per cent of lead, and 5 per cent of zinc. It is also regarded as a good bearing metal for general service.

Oval Chuck. An oval chuck, also known as an elliptic chuck, is a work-holding device used in the lathe for holding and revolving work that is to be turned to an oval or elliptic shape. See Elliptical Chucks.

Overhead Expenses. The term "overhead" or "overhead expense" generally includes all items of cost that cannot be directly charged as wages of productive labor or as cost for materials used in actual manufacturing. Such expenses include such items as salaries of company officials and supervision in the shop, general office expense, office supplies, advertising, selling expense, traveling expense, losses from bad debts, power, light, heat, insurance, taxes, depreciation, general repairs, and shop supplies, shipping expense, storekeeping, purchasing, accounting, inspection, safety work, engineering and drafting-room expense, and research work. In different plants, there would evidently be different items that would have to be charged to overhead, but generally speaking, it includes costs that cannot be charged to productive labor and the cost of materials.

Overhead Expenses, Machine-Hour Distribution. The machine-hour rate method consists of distributing all the manufacturing expenses of an establishment by a charge to each job of the overhead cost of operating the machines and other facilities used on that job. This overhead charge is not an average for the whole plant or department, but is, as nearly as possible, the actual overhead cost of maintaining and operating each of the machines, group of machines, benches, etc., which are found in the plant. By the proper use of this method it is possible to show the difference between the expense cost of a boring mill and a lathe, a gear-cutter and a splining machine, etc.

To install a machine-rate method, the number of feet of productive floor space available for manufacture is first found, eliminating the space used for foremen's offices, stairways, washrooms, stock-rooms, etc. The number of square feet so obtained

is used as a divisor for determining the cost per square foot per year for maintenance, depreciation, taxes, insurance, and other kindred charges applying against the land and building. No expenses are included in this group that are incident to the actual operation of the machines, but only those charges that apply against the empty building ready for manufacture. However, the expense of lighting and heating the building and charges of a similar nature are included. In this way a charge per square foot is obtained which is practically the same charge as the owner of a building would make if he rented it and furnished the light, heat, and water used in the building, except that he would include a profit on his investment. The factory is divided into production centers, including in each center machines of a similar type located together, or individual machines where there are no convenient groups. Different kinds of machines should not be included in one production center, as this would defeat the object of the system. After the division into production centers has been made, the number of square feet occupied by each center is determined, including in this area the space required for the material waiting to go on the machines, the space required for the workman, etc., and each center is charged with a part of the rental of the whole building based upon the area occupied. This division gives the rent per year for each production center, and in this way the total charges of the building which we have called rental charges would be allocated to various production centers. Thus it will be seen that one part of the expenses is now divided in such a way that these items can be included as one factor in the machine-hour rate.

The next step is to determine the actual cost of the expense items incident to the operation and maintenance of each of the production centers. These expenses consist of depreciation of the machinery and equipment, taxes, repairs, small tools, cutting oils and other charges which can be definitely allocated to the machines that have been included in one production center. If a small group of machines, all included in one center, requires the entire time of one foreman, the wages paid this foreman would be included with the other expenses in arriving at the total cost of operating the centers. The distribution of the power charge can best be made on the basis of the horsepower required by each production center. In this power charge we would include the expense of running the power plant as well as the shafting, belting, etc.

The expenses under consideration should cover a period long enough to insure correct results, as well as a period of normal operations so that the results will represent the hourly cost of operating the production centers in normal times and under nor-

mal conditions. The best results are obtained if the expenses for a whole year are used as a basis for the machine-hour rate; and if these expenses are carefully analyzed and allocated to the various production centers, the hourly rates first determined will not require much adjustment. In fact, the success or failure of the system depends on the amount of attention given to the division of the expenses at the beginning, as, unless the first rates are approximately correct, the first results obtained from the system will be so disappointing and misleading as to cause a manufacturer to condemn it and to insist for all time that the plan is no good. We will assume that the expenses analyzed cover a period of one year.

Two groups of the annual expenses are now divided among the various production centers, and by adding the rental charges and the charges for operating and maintaining the machines, we have the basis for determining the hourly cost of expense applicable to work on the machine-hour basis. To determine the hourly charge, the total normal hours which each production center will work per year is estimated; then the amount of the expenses allocated to each production center is divided by the normal hours this center should operate, and the result is expense cost per hour.

There still remain a few items of expense which have not been distributed, such as supervision, clerical, and general administrative expenses. These expenses should be totaled, and the total divided by the sum of the normal hours of all the production centers. The result of this is another hourly expense cost which must be added to each machine rate as a supplementary charge.

The machine-hour rate is based entirely on the assumption that the production centers will work a certain number of hours in a certain time, a year having been used as the basis. It is obvious that no man can predetermine accurately the number of hours any machine in his plant will be occupied, and many people reject the idea of installing this system for that reason alone. However, a close approximation of the normal working time of any machine can be found, either by keeping records or examining records already available, and if the expenses of operating the machine are based on an approximately correct operating time, we have, by the machine-hour rate method, a means of showing immediately the financial effect of any variation of the operating time of the machines from the predetermined normal or standard operating time.

In making up the hourly rates, we assume that we had a certain amount of expense, say $1200, to absorb in a certain period, say one year, over one production center. Let us say that we estimated the normal hours that this center would be used in the year

to be 2400, or 200 per month. On this basis, the hourly expense cost of operating this production center is fifty cents. By adding fifty cents for each hour that a job required the facilities of this production center, we would expect to absorb all the expenses connected with it. Now, if the jobs passing through this center in a month required the use of the facilities for only 180 hours, we would see at the end of the month that on this particular center we had failed to absorb $10 of our expenses. We would have the same information for all other centers, and, therefore, for the whole shop, and would know at the end of the month how much of the manufacturing facilities had not been used or had been used more than we expected, this information being available both in terms of hours and money.

When comparing the way in which expenses are distributed by machine-rate costs with the distribution by means of any other method, it will be seen that, as far as accuracy is concerned everything is in favor of the machine-rate method. All other methods of absorbing manufacturing expense depend in one way or another on averages, and yet there is no more reason for averaging the expenses over costs of all the work produced than there is for averaging the material items.

Overhead Expenses, Man-Hour Distribution. The man-hour method of distributing overhead has for its base the number of hours spent on a job instead of the amount of wages paid. This method is subject to the same criticism as the man-rate method in that the assumption is made that the overhead expenses have a fixed ratio to the number of hours of time spent on a job. The advocates of this method point out that certain items of expense do bear a direct relation to the number of hours worked, and include under this head the expenses of the payroll and welfare departments, compensation, insurance, and supervision. To a certain extent these items do bear a closer relation to hours worked than to wages paid, but as they represent a small part of the total expense, and as it would be erroneous to distribute the major part of the overhead on this basis, there is no advantage in this method over the man-rate basis. Moreover, if it is the policy not to reduce the payroll and supervisory force every time business falls off, the cost per man-hour would fluctuate sufficiently to nullify any advantage gained over the man-rate method particularly where this advantage consists chiefly in compensating for the difference in labor rates by substituting hours worked for wages paid.

Overhead Expenses, Man-Rate Distribution. The man-rate method of distributing overhead costs is the one in most general use because of its simplicity. To use this method, it is only necessary to find the ratio of total expenses to total labor for a given

business, and to apply this ratio to the labor cost of each job For a factory making one kind of product, this method of distributing overhead is quite satisfactory, but where the product itself is varied and the tools used in getting out the product are different for each of the various units produced, this method is incorrect and misleading as to final results. According to the man-rate method the highest paid workman requires the most overhead expense, when actually the lowest paid man often requires the most supervision, and frequently the machine tools used by the low-priced man are more expensive and require greater expenditures for operation and maintenance than those used by the skilled mechanic, because there is incorporated in the machine which enables lower grade labor to be used the skill that the high-grade man has in himself. Thus, if a semi-automatic machine is used for making any part, a man who is not an expert mechanic can be employed to run this machine or even several of these machines, but if this special equipment were not used a skilled man would be required to be in constant attendance on a simpler machine. It is obvious in this case that the overhead expense that is incurred in running the automatic machine is much greater in proportion to the wages paid the operator of these automatic machines than is the overhead incurred in running the mechanical equipment required by the skilled mechanic.

It is also true that even if the same wages were paid all men in a manufacturing establishment, it would still be wrong to apply the overhead to each job on the basis of a percentage of labor cost, for we would still have the condition of one man running more machines than another and of the difference in cost of the machines operated; also that some men would be occupied on jobs such as cleaning castings, checking finished product, painting, etc., which require little mechanical equipment and therefore do not increase the overhead expense at the same rate as their wages increase the direct labor payroll. From the foregoing, it would appear that the man-hour rate method of distributing expenses is a dangerous one, in some instances. There are cases, however, where this method may give results which will be satisfactory from the standpoint of profit, as cited in the following:

In a manufacturing establishment where the mechanical equipment is fairly well standardized, where the product, while varied as to different types, still has the same average types of output, and where these types all require substantially the same machining operations, it will be found that the ratio of profit to total output will come up to expectations when the man-rate method of distributing overhead is used. There is also a factor that must not be overlooked when considering any business, and that is, the amount of information which the man or men at the head of it

have of that business independent of records; frequently when estimating the cost of new work, allowances are made by the owner of a business for a higher expected cost due to special facilities which will be necessary and to the expectation that the bigger machines in the plant will be used on the work. By making such allowances, the final price submitted includes some of the factors of expense cost that are not actually subject to proof from any records of overhead expense which would be available if the man-rate method of distributing overhead were in use.

Overhead Expenses, Material and Labor Distribution. The application of overhead on the basis of prime cost (material and labor) does not seem to be in very general use. This method requires that the total expenses of a business be divided by the sum of the direct labor and direct material and that the ratio or percentage so obtained be applied to the direct material and labor cost of each job turned out. It is manifestly wrong to apply this method to the product of a business that uses various kinds of material, but, where the product is all made from iron or steel, this method has some good points, as, by taking the material into consideration as well as the labor, we apply more accurately the expense of handling the material in the shop which, of course, varies with the size of the piece handled.

This method has many of the same kind of inherent defects as the man-rate and man-hour methods, as we would still be applying an average expense to jobs instead of an actual cost, the difference between this and the other two systems being only that the material is added to the labor before determining the expense to be applied. Even were this method correct for some kinds of business, the places where it could be applied would be limited in number, and this method could never be applied generally.

Over-Hung Bender. This is a bending machine for angles, channels, and other structural shapes in which the rolls are placed outside of the housing. These machines are not adapted for very heavy work, but the rolls are easily adjusted and can readily be taken off and replaced with rolls of a different shape.

Overload Prevention. Some types of machines are so arranged that any unusual resistance to motion will automatically stop either the entire machine or whatever part is affected, in order to prevent damaging the mechanism or straining it excessively. A simple form of safety device consists of a pin which shears off or breaks in case the overload becomes excessive. This method of protection against overload has been applied in various ways, and, while it is simple, there are certain disadvantages, one of which is that in order to avoid replacing a broken pin, the machine operator sometimes inserts a pin that is stronger than it

should be. The ideal safety device is one which does not break in case of overload, but simply disengages and is so arranged that it can readily be reengaged. In electrical work, this principle has been applied by substituting circuit-breakers for fuses which melt when the current becomes excessive.

Automatic Relief Mechanisms for Forging Machines: Forging machines are equipped with a tripping or relief mechanism which prevents excessive straining or breakage of the parts controlling the motion of the movable die, in case the stock to be forged is not placed in the grooves of the dies, but is caught between the flat faces. These relieving mechanisms differ somewhat in design, but the object in each case is to temporarily and automatically release the movable die from the action of the driving mechanism, in case the operating parts are subjected to a strain or pressure that is abnormally high. The release may be obtained by inserting bolts or "breaker castings" in the mechanism, which will shear off or break if there is an excessive strain; another type of relief mechanism depends for its action upon a spring which is proportioned to resist compression for all ordinary strains but to compress sufficiently to release the pressure on the dies when that pressure increases beyond a safe maximum.

Overload Trip. An overload trip is an arrangement which releases the holding latch of the circuit-breaker when the current, flowing through the circuit in which the breaker is connected, exceeds a certain predetermined amount, the tripping being accomplished by the armature of the magnetic circuit when forced against the holding latch by the attraction of the magnet.

Oxidation. One of the most common forms of chemical energy is *oxidation,* which is the combining of oxygen with various elements and compounds. The corrosion of metals is generally a form of oxidation; rust on iron, for example, is iron oxide. When oxidation becomes rapid, it is known as *combustion,* and the substances acted upon are termed "combustibles." When the combustion is extremely rapid and is accompanied by noise, it is termed *explosion,* and the matter that explodes is called on "explosive mixture."

Oxidizing and Reducing Agents. Any substance that causes an element or compound to combine with oxygen is called an *oxidizing agent.* A substance that removes oxygen, or elements similar to it, is called a *reducing agent.* Reducing agents are especially useful in obtaining metals in the free state from their ores.

Oxy-Acetylene Method of Cutting Steel and Iron. The process of oxygen cutting of steel, wrought iron, and cast iron

consists of burning the metal along a predetermined path with a jet of oxygen after the metal has been preheated at the starting point to a bright red heat. Only the red hot metal in the path of the oxygen jet burns, while the cooler metal adjacent is unburned and practically unaffected beyond a narrow zone, usually less than 1/16 inch on each side of the cut.

The heating, preparatory to cutting, is done by a small flame or flames close to the central orifice in the torch tip through which the oxygen cutting stream issues. The gas for the preheating flame that has given the most general satisfaction is acetylene; hence, the process, when acetylene is used for preheating, is known as "oxy-acetylene cutting." The number of heating flames varies from one to six—seldom more. One flame is rarely or never used, but it is seldom that more than four or five are required, except when cutting cast iron. The use of four or five preheating flames insures that one or two flames will always be ahead of the oxygen jet when cutting in any direction in a plane parallel to the surface of the piece cut.

The use of fabricated steel plates and structural shapes, assembled by welding, has greatly increased for such purposes as machine bases, frames, housings, uprights, rotors, and other machine parts and oxygen cutting has proved a convenient and economical method of cutting steel plates to the shapes required for work of this kind.

Hand Torches for Oxy-acetylene Cutting: Oxy-acetylene cutting was practiced at first with hand torches exclusively, and the hand torch is still the principal gas cutting tool. The operator holds the torch at the required height from the work and follows the line of the cut. He must move the torch steadily to keep in step with the cutting action. If the torch is moved along the cut much faster or slower than the cutting action, the cut is "lost," and a new start must be made.

As with other hand operations, the accuracy, smoothness, and efficiency of the cutting depends upon the skill and care of the operator. The thicker the metal, the more difficult hand-cutting becomes, owing to the slow rate of progress required, compared to most hand movements, and the necessity of holding the torch so that the cutting edge will be projected squarely through the piece. Slight variations in the side angle at which the torch is held, and variations in speed that might have little noticeable effect on thin plates, are likely to produce shape defects when thick plates, slabs, and forgings are being cut. The shape of the cut is likely to have one form at the top surface and another at the bottom. This reduces the efficiency of the cutting operation. Efficiency in cutting refers to consumption of oxygen and acetylene, as well as to the cutting time. The volume of oxygen used is

almost directly proportional to the volume of steel oxidized and displaced in the cut. The wider the kerf, the greater the weight of steel burned away and the larger the volume of oxygen used. The hand-operated torch cuts a wider kerf than a mechanically-guided torch, because the former wavers slightly from side to side and the cutting jet covers a wider area.

Machines for Oxy-acetylene Cutting: Machines for "gas cutting" are designed to hold and guide the torch mechanically and propel it along the required path at a uniform rate that is varied to suit conditions. Such cutting machines are made in portable, semi-portable, and stationary types. In shipyards, bridge works, and industrial plants where a large tonnage of steel plates is handled daily, requiring trimming, splitting, beveling, and cutting to length, portability is important.

One type of portable machine is known as the "Radiagraph." This machine carries a straight-head machine-torch with means of setting the torch at any angle required for beveling or cutting a calking edge. A compound slide rest provides for vertical and horizontal adjustments. The carriage of this machine has three small wheels, two being tractors and the third a free wheel. When straight lines are being cut, the wheels run on a grooved track and when circular arcs or circles are being cut, the machine revolves around a pivot point fixed to a radius rod. In the latter case, only one of the tractor wheels is used for a drive, and the free wheel, which is mounted like a caster, follows the path set by the radius bar. This machine is used largely for fabricating shapes from steel plates or slabs.

Cutting Duplicate Parts to Shape of Master Cam or Templet: A semi-portable machine, known as the "Camograph" can be taken to the job or, when the parts are easily handled, used in a stationary position. The torch is mounted on a vertical slide at the outer end of a double hinged arm. The hinged arm is supported by a vertical post fixed in a base. At the top of the post is a cam-holder designed to hold, in a horizontal position, an internal cam or templet having an opening, the shape of which is approximately the shape to be cut. In contacting with this inner surface is a magnetic roller driven by a variable-speed motor. As the magnetic roller turns on its axis it follows the cam shape and carries the straight-head torch with it, cutting the shape below. Only one shape can be cut with a cam; hence, this is a repetitive production cutting machine. Boiler hand-holes, hand-hole covers, rubber heel dies, and tube supports in water-tube boilers are a few of the shapes cut with this machine.

Multiple Oxy-acetylene Cutting: Machines have been designed for multiple cutting of shapes, using two or more torches on one thickness of steel plate; for cutting in multiple from a stack of

two or more plates with one torch; or for cutting shapes from a stack of two or more plates with two or more torches. The conditions that must be met in multiple cutting are more exacting than with single piece cutting of a thickness equal to the height of the stack.

Thickness of Metal that can be Cut: The maximum thickness of metal that can be cut by high-temperature flames depends largely upon the gases used and the pressure; the thicker the material, the higher the pressure required. Steel slabs 18 inches thick are within the range of standard practice. A mechanically-guided torch will cut thick material more satisfactorily than a hand-guided torch. With any flame, the cut is less accurate and the kerf wider, as the thickness of the metal increases. When cutting light material, the kerf might not be over 1/16 inch wide, whereas, for heavy stock, it might be ¼ or ⅜ inch wide.

Oxy-Acetylene Welding. The high temperature required for autogenous welding is obtained usually by the combustion of acetylene gas and pure oxygen. These gases are thoroughly mixed in the nozzle or tip of the welding torch to insure perfect combustion. The weld may be formed directly between two adjoining surfaces, but usually metal from a welding rod is fused in between the surfaces of the joint. The rod or wire used may or may not have the same composition as the material being welded.

This welding process may be applied to cast iron, steel, brass, copper, aluminum and other ferrous and non-ferrous metals. For ordinary welding operations the equipment consists of containers for the oxygen and acetylene gases, with suitable reducing valves, pressure gages, and hose connections with the welding torch. In manufacturing plants where oxy-acetylene welding or metal-cutting apparatus is used more or less continuously, and especially on duplicate work in quantity, special tools, fixtures and machines are employed for holding the work and guiding the torch mechanically.

Oxy-acetylene Flame: The combustion of acetylene in oxygen produces an extremely high heat. The temperature produced by the oxy-acetylene flame is estimated at about 5400 degrees F. The flame of acetylene is much hotter than that of hydrogen, and the number of heat units per cubic foot of gas is about five times as great, the ratio being as 330 to 1600. Hence, both the intensity and amount of heat of the oxy-acetylene flame, as compared with other heat-producing mediums, are superior. The oxy-acetylene flame is used for cutting metals, in addition to its use for welding. When iron and steel are heated to a high temperature, they have a great affinity for oxygen and readily combine with it to form different oxides, which cause the metal to be disintegrated

and burned with great rapidity; this is the principle governing the operation of a cutting torch. See also Cutting Metals with Oxidizing Flame.

Oxyacid. Oxyacid is an acid which contains oxygen. Its name is generally formed by adding "-ic" either to the name of the element with which the oxygen is united or to an abbreviation of that name, as, for example, sulphuric acid and phosphoric acid. If the element forms two acids with oxygen, that which contains less oxygen usually ends in "-ous." The acid which contains still less oxygen than one ending in "-ous," is designated by the prefix "hypo-"; those containing more oxygen than one ending in "-ic" are designated by the prefix "hyper-" or "per-."

Oxygen. Oxygen is one of the chief constituents of the atmosphere, in which it is present to the extent of 21 per cent by volume or 23 per cent by weight. The atomic weight of oxygen, which is taken as 16, is used as a standard by which the atomic weights of other elements are compared and determined. The specific gravity of oxygen (air = 1) is 1.106. Its specific heat at 32 degrees F. is 0.217. It becomes liquefied at a temperature of —183 degrees C. (—297 degrees F.), and solidifies at a temperature of —235 degrees C. (—391 degrees F.). Oxygen does not itself burn, but it is the greatest supporter of combustion known, and nearly all other chemical elements combine with it under evolution of heat. Oxygen is used in many industries; in the machine industries, it is used in large quantities for oxy-acetylene and oxy-hydrogen welding of metals and cutting of iron and steel.

Oxygen and Nitrogen in Steel. Oxygen and nitrogen are very injurious to steel and decrease its strength and wearing qualities. When titanium is added to the molten metal, it combines with these gases, which otherwise are liable to become occluded in the steel, and carries them off into the slag. These gases also form miniature bubbles that, when segregated, form holes large enough to be seen plainly. If segregated in large enough masses they form good-sized blow-holes. Owing to the gaseous nature of both oxygen and nitrogen, it has been difficult to analyze steels for these contents. Investigations, however, showed that the percentage of oxygen in some twenty-four samples of steel ranged from 0.021 to 0.046 per cent. Even these small percentages are high enough to materially effect the qualities of steel.

Investigations have shown that, at first, an increase of nitrogen causes the toughness of steel to slightly increase, but reduces its ductility; each increase of nitrogen causes the elongation to rapidly diminish. Steel with 0.5 per cent of carbon loses its ductility in the presence of from 0.040 to 0.047 per cent of nitrogen.

Open-hearth steel usually contains from 0.020 to 0.025 per cent of nitrogen; Bessemer steel from 0.018 to 0.062 per cent; and crucible steel has from 0.010 to 0.015 per cent in nitrogen. Titanium has a very strong affinity for both oxygen and nitrogen; it forms with oxygen an oxide, and with nitrogen, a stable nitride that shows as tiny red crystals under the microscope. Both of these are then carried off into the slag and the quantity of slag that is lifted from the molten metal is quite materially increased. The deoxidation of steel is usually accomplished with manganese and silicon, but these never remove the oxides as thoroughly as is desired. Titanium is a much more powerful deoxidizer than either or both of these; when added to steel at the time of tapping, it completes their unfinished work and reduces the oxygen and nitrogen to mere traces.

Oxygraph. The oxygraph is a machine used for cutting steel by the oxy-acetylene process, and is employed when it is required to follow a certain outline or pattern. The device is constructed on the pantograph principle.

Oxy-Hydrogen Flame. Hydrogen gas burns readily in oxygen or air. When the combustion of hydrogen is sustained by pure oxygen, a very high temperature (about 4000 degrees F.) is produced. Many forms of oxy-hydrogen lamps and blowpipes have been invented to make use of the high heat produced by the combustion of hydrogen. The flame is used for autogenous welding and cutting of metals and in platinum works, because the latter metal is fusible only in the oxy-hydrogen or oxy-acetylene flame and in the electric furnace. The oxy-hydrogen flame, or, more properly speaking, the air-hydrogen flame, is used extensively in lead burning, which is a process similar to that used tor the welding of iron, steel, and other metals, by means of the oxy-acetylene flame. Hydrogen—with air to sustain the combustion—is used for lead burning instead of acetylene, because lead melts at a low temperature, and the high heat produced by acetylene burning in oxygen makes the welding of lead by it very difficult, if not impossible. Air is also used instead of pure oxygen for the combustion of the hydrogen in order to reduce the temperature of the flame.

Ozalid White-Print Process. This process for obtaining reproduction of tracings produces a positive print or dark lines on a white background, by dry development. See Positive Prints.

Ozonators. An ozonator or ozonizer is an electrical apparatus for producing ozone for the purification and deodorization of air under various conditions. The essential parts of an ozonator are the transformer for obtaining a sufficiently high voltage and the generating units.

P

Pack-Hardening. Pack-hardening as usually conducted is actually carburizing, the only departure from the process, in general, being that the temperatures of the heats are lower. Correctly speaking, pack-hardening is the process whereby high-carbon steels or steels that will harden without the aid of carbon added by carburizing, may be protected from furnace gases and air. By packing in some carbonaceous material, the work is protected by the carbon gases given off, and in quenching from the pot, the work is clean and free from scale. A valuable point in favor of this operation is that the work is brought to the quenching temperature slowly and uniformly, and so dangers of cracking and warpage are reduced to a minimum. Any carburizer can be employed in packing, used material being the best, as the carbon strength of the gas is lower and there is less danger of carburizing the work. The danger of decarburizing is slight, provided the lowest temperature that can be used for hardening the work is employed. The length of time of the operation has a tendency to increase the grain size, which is augmented by high temperatures. It is dangerous to carburize the surface of high-carbon steel, because a line of demarcation between the case thus produced and the case of the original steel will shorten the life of the part. Minute surface cracks usually develop after hardening.

Common hard wood charcoal is recommended for pack-hardening, especially if it has had an initial heating to eliminate shrinkage and discharge its more impure gases. The work is packed as in carburizing and in the same type of receptacle. The pack-hardening of high-speed steels is extensively done. There are many tools which are so delicate and have such a variation in cross-section that only with extreme care can they be hardened in the open furnace and preserve the delicate edges and corners.

Packing. Packing is used on engines, pumps, and machinery of various classes to seal joints either between stationary or movable parts, in order to prevent the leakage of steam, air, water, or any other gas or fluid. Packing is made in many different forms and is applied in various ways. For instance, packing in the form of thin sheets or rings of some flexible material is placed between pipe flanges, cover joints, etc., to prevent leakage. Other forms, which may be of square or circular cross-section, are applied to valve stems, engine piston-rods and in general, wherever a tight joint is required. A great variety of materials are used for packing, the particular material used depending somewhat

upon the class of service and also upon the preference of the designer or engineer. Whatever the composition may be, the essential qualities are elasticity, durability, and, in the case of packing for a moving part, a low coefficient of friction and practically no wearing or abraiding effect.

Packing Materials. The packing materials formerly used were hemp and cotton fiber, but much of the packing now used for certain classes of service is made of combinations of cotton (in the form of canvas) with rubber. The rubber provides the necessary elasticity and the canvas absorbs and holds the lubricant. Paper fiber has also been extensively used, as well as hemp with graphite. For some purposes, these fiber and rubber packings have been inadequate, either because of high pressures or high temperatures. In order to secure a more durable packing and one that would resist both heat and an excessive pressure, the metallic form of packing has been extensively used, especially for steam engine piston-rods. There is a great variety of packing adapted to steam work which may be classified as fibrous and metallic, although it may be combined in many different ways, together with rubber, graphite, and other materials. The metallic packing is formed of a series of rings composed of some soft alloy, and so arranged that end-wise compression, from a spring within a gland, will cause the rings to contract upon the rod.

There are various forms of shredded packing, both metallic and fibrous, which are mixed with certain lubricating substances and packed in the stuffing-box. Packing of this kind is also put up in thin cotton tubes, two or three feet in length, which are wound around the rod the same as wicking. Ring packing made up of various substances is a very efficient and convenient form.

Paint, Aluminum. See Aluminum Paint.

Paint, Heat-Reflecting. See Aluminum Paint.

Paint, High-Temperature. Paint that will withstand high temperatures, even up to a red heat, has the following composition: Lampblack, 3 pounds; graphite, 3 pounds; black oxide of manganese, 1 pound; Japan gold size, 1 pint; turpentine, 1.5 pint; and boiled linseed oil, 1 pint. Powder the graphite and mix all the ingredients to a uniform consistency; give two coats. The following mixture is also recommended: Black oxide of manganese, 2 pounds; graphite, 3 pounds; and terra alba, 9 pounds. Mix and pass through a fine sieve, then mix to the required consistency with the following compound: Sodium silicate, 10 parts; glucose, 1 part; and water, 4 parts.

Palladium. A rare metal that is lighter than but not as expensive as platinum. It is a silvery colored element whose atomic number is 46, atomic weight, 106.7, and which has a melting point of 1554 degrees C. Alloys of this metal are used for electrical contacts, instruments, and jewelry.

Panel or Thickness Planer. This type of wood-working machine is also known as a "surfacer" and may be either single or double, depending upon whether it operates on one or on both sides of the board at the same time. It does not make a plane surface, as the stock is fed through rollers which hold the piece straight while the cutters are in operation, but the work resumes its original form as soon as the pressure is relieved. The single type used in combination with the hand jointer is the best for pattern-shop work. The stock is first jointed on one side and planed to thickness on the panel planer.

Pantograph Mechanisms. A pantograph is a combination of links which are so connected and proportioned as to length that any motion of one point in a plane parallel to that of the link mechanism will cause another point to follow a similar path either on an enlarged or a reduced scale. Such a mechanism may be used as a reducing motion for operating a steam engine indicator, or to control the movements of a metal cutting tool. For instance, most engraving machines have a pantograph mechanism interposed between the tool and a tracing point which is guided along lines or grooves of a model or pattern. As the tracing point\moves, the tool follows a similar path, but to a reduced scale, and cuts the required pattern or design on the work.

Pappus Rule. See Guldinus Rule.

Parabola The parabola is a curve of that class known as *conic sections*. The parabola is obtained by taking a section through a cone parallel to the side of the cone. If a parabola rotates about its own axis, the parabolic curve will describe a surface which includes a solid body known as a *paraboloid.*

Parallel Connection. In any electrical circuit, two or more elements such as resistances, inductances, condensers, lamps, motors, etc., are said to be connected in parallel when a common connection joins one terminal of each element and another common connection joins the remaining terminal of each element. See also Series Connection.

In electric batteries, when all the anodes or positive electrodes of a battery are connected together and all the cathodes or negative electrodes are connected, this is known as a parallel connection. With such a connection the result is the same as if the battery were a single cell having elements of the same area as

the area of the combined anodes and combined cathodes. The electromotive force is the same as that of one single cell, but the resistance of the battery will be that of one cell divided by the number of cells; hence, the amount of current is increased, being equal to the current of one cell multiplied by the number of cells. See also Batteries.

Parallelepiped. A parallelepiped (sometimes also called *parallelepipedon*) is a solid body bounded by six plane surfaces, all of which are parallelograms. Each two opposite surfaces are parallel and equal to each other. A parallelepiped may also be defined as a prism, the end surfaces or bases of which are parallelograms.

Parallel Motion. See Straight-line Motions.

Parallelogram. A plane figure bounded by four straight sides, of which those opposite each other are parallel, is known as a *parallelogram*. The square and rectangle are parallelograms in which all of the angles are right angles. It is not necessary, however, that the angles be right or 90-degree angles; sometimes two of the angles are less and two more than 90 degrees. The sum of the angles is always equal to four right angles.

Parallels. Parallels are placed beneath parts to be planed or ground, usually for the purpose of raising them to a suitable height, or to align a finished surface on the under side with the platen, when such a surface cannot be placed in direct contact with the platen. These parallels are made in pairs of different sizes, and opposite sides are parallel to each other.

Paraloy No. 2. A nickel-chromium alloy cast iron containing nickel, 2 to 4 per cent; chromium, 0.75 to 1 per cent. Brinell hardness, 250 to 300, and tensile strength, 40,000 to 50,000 pounds per square inch before heat-treatment; after heat-treatment: hardness, 450 to 550 Brinell, and tensile strength, 30,000 to 40,000 pounds per square inch. Suitable for cast dies for sheet-metal stamping and drawing operations.

Paramagnetic Substance. If a substance has a magnetic permeability greater than that of a vacuum, it is called a *paramagnetic* substance. Most substances are very slightly paramagnetic; but the only substances that are strongly paramagnetic—that is, that have a permeability considerably greater than that of a vacuum—are iron, steel, nickel, and cobalt, and certain of their alloys. For the purpose of distinguishing these materials from those which are only slightly paramagnetic, the term *ferromagnetic* has been applied. A paramagnetic substance is the opposite of a *diamagnetic* substance, which latter has a permeability less than that of a vacuum. Of all materials, bismuth exhibits the strongest diamagnetic property. Silver and copper

are also diamagnetic, but in a considerably less degree. All the elements, except iron, steel, nickel, cobalt, and bismuth, are, from a practical standpoint, generally considered to be non-magnetic.

Parentheses. Two important rules relating to the use of parentheses are based upon the principles of positive and negative numbers:

1. If a parenthesis is preceded by a $+$ sign, it may be removed, if the terms within the parentheses retain their signs.

$$a + (b - c) = a + b - c.$$

2. If a parenthesis is preceded by a $-$ sign, it may be removed, if the signs preceding each of the terms inside of the parentheses are changed ($+$ changed to $-$, and $-$ to $+$). Multiplication and division signs are not affected.

$$a - (b - c) \quad = a - b + c.$$
$$a - (-b + c) = a + b - c.$$

Parkerizing. Parkerizing is a chemical conversion rustproofing process whereby the surfaces of iron or steel are changed to an insoluble phosphate coating that is highly resistant to corrosion when combined with stain, oil and wax finishes. The process is especially adapted to treating forgings, castings, stampings, screw machine and wire products, on which paint finishes are not necessary or desirable. It produces a deep black color and may be painted when desired.

Parsons' White Brass. This is an alloy of tin, zinc, and copper, frequently known as "Parsons' white bronze." This alloy has the essential characteristics of hard babbitt.

Parting Sand. Parting sand is a fine shore or river sand used in molding to prevent adjoining bodies of sand from adhering. It is sprinkled on the joints of molds to prevent the sand in the cope and drag from adhering to each other.

Passow Cement. A cement known as Passow cement is made by granulating blast furnace slag and finely grinding the product, either alone or with an addition of about 10 per cent of Portland cement clinkers. Passow cements are claimed to produce a material which sets rapidly and which attains a strength comparable with that of Portland cement.

Paste Binder. This is a paste made of flour and water, used for holding together the sand in dry sand cores. This binder is especially used for long, slender cores.

Pasted Plate. See Faure Plate.

Patch Bolt. A bolt provided with a countersunk head on the top of which a square head is provided; such bolts are used for fastening patches in the repair of boilers. Holes in the patch or plate are countersunk for the heads of the bolts and the boiler plate holes are tapped. After the bolts have been screwed securely into place, the square heads are removed, and the bolt heads and edge of the plate are calked to prevent leakage.

Patch-Bolt Taps. Patch-bolt taps are only a modified form of taper boiler taps. The taper is the same, ¾-inch per foot, but the threaded portion as well as the total length is shorter than the corresponding lengths of a taper boiler tap. Patch-bolt taps are always provided with 12 threads per inch irrespective of diameter.

Patenting. A term applied to the heating of steel above its critical temperature range followed by cooling to below that range in air, in molten lead, or in a molten salt. This treatment is applied in the wire industry as a finishing treatment or as a treatment preparatory to further wire drawing.

Patented Rods: Rods of medium or high carbon content which have been given an individual strand heat treatment in preparation for drawing into wire. The temperature employed in this operation is above the critical range and heating is followed by comparatively rapid cooling.

Patents. A patent is a monopoly securing to an inventor the exclusive right of exploitation of his invention for a certain period of time provided he complies with certain rules and regulations to obtain his patent. The general idea is that a patent is a contract between the inventor and the Government. The inventor discloses his idea to the public in the form of a patent and thereby bestows a benefit on the public. In return for this benefit the Government gives the inventor a monopoly on his invention which lasts, in the United States, for 17 years from the date of issue of the patent.

Invention: What is invention? Some courts have stated that the term defies definition; some courts have tried to define it, but the laws relating to patents apparently take it for granted that everybody knows what it is. It seems to be a peculiar quality of the human mind which enables us to produce new results by combining and recombining elements. There must be something of this quality present in order to entitle you to a patent. There must be something of this gift of seeing things which others do not see to make an improvement an invention. This does not mean, however, that inventions made in chemical laboratories as a result of the so-called trial-and-error method are not patentable. There is probably little use in trying to positively define the term invention, but many rules have been established to show what is *not* invention.

Novelty in Invention: As in connection with the term "invention" the law has not attempted to define novelty but has established a number of rules to show when an invention is not novel. In other words, the law takes it for granted that your invention satisfies the requirement of novelty unless it can be shown that, under a set of positive provisions, your invention is not novel. An invention lacks patentable novelty if:

1. It was known or used by others in the United States, before the date of the invention, or

2. It was patented or described in any printed publication in this or any foreign country, (a) before the date of the invention; or (b) more than one year prior to the application. (Under the act of August 5th, 1939, the former two-year periods were reduced to one year, beginning August 5th, 1940.)

3. It was in public use or on sale in the United States for more than one year prior to the application. (This period prior to August 5th, 1940, was two years.)

Utility Patents and Design Patents: Patents are divided into two groups, *utility patents* and *design patents*. The former are intended to cover inventions the object of which is to enhance the usefulness of an article while the design patent covers inventions the object of which is to enhance the aesthetic appearance of a device. The design patent is rather closely related to the Copyright, the difference being that a copyright protects, in addition to works of literature, works of the so-called fine arts, while a design patent protects works of the industrial arts. The utility patent is the one which is most commonly used. While the prosecution of a design patent application, trademark application and copyright application is, more or less, a routine matter, the prosecution of a utility patent application calls for a high degree of skill and knowledge and the value of the Patent depends largely upon the skill with which the application has been prosecuted through the Patent Office.

Patent Rights. Considerable difficulty has arisen between employes and employers relative to the ownership of patents that are issued in the name of an employe without the knowledge of the employer. The holding of the United States Supreme Court is to the effect that if a patent is issued in the name of an inventor, and relates to an invention conceived, experimented with, and perfected on his employer's time, the true ownership of the patent lies with the employer. Of course, all these facts must be proved before a court will issue an order requesting the Patent Office to transfer the title of a patent already issued, from the name of the inventor to the employer.

Invention Made on Workman's Time: Simply because an inventor is employed and paid to perform certain duties, the employer cannot, ordinarily, claim the ownership of an invention that an employe conceives and perfects while not engaged in performing his regular duty. In other words, an employer has no common law rights of ownership in an employe's invention which is made entirely on the employe's time, unless a contract to that effect exists or there is a written agreement between the employer and employe. Therefore the old custom of having contracts seems to be logical at present, the same as it was previous to the later court decision.

For many years it was customary to provide a written agreement between the employer and his workmen, wherein the employes specifically and unmistakably agreed to assign all the patent rights to the employer on inventions made while working on the employer's time. During those years the existence of such a contract was necessary in order to assure the employer that he would receive the benefits of the inventive faculty and ability of the employes, even though the inventors actually were paid to design and invent new things.

Contracts Which Protect Employer: At present, a signed contract in which an employe unmistakably agrees to assign to his employer all inventions made on the employer's time, may eliminate litigation wherein the employer would be required to prove that the invention in controversy was perfected specifically in accordance with the present established law. Furthermore, an additional clause may be added to this contract in which the employe agrees to assign the patents on all inventions relating to kindred lines of business in which the employer is engaged, whether the inventions are conceived and invented on the employer's time or while the employe is in his own home, or elsewhere. The latter clause gives the employer important advantages, particularly for the reason that it may not be necessary for him to prove that the inventor actually did work on or perfected inventions on the employer's time, which is often very difficult to prove.

Protection of Both Inventor and Employer: It is well to thoroughly understand that while the present law takes into due consideration the rights of an employer relative to the ownership of an invention made in his factory, even where no contract exists, nevertheless, the law also protects the inventor who may patent an invention conceived and perfected while he may be at his own home, or other places, during periods when he is not receiving remuneration from his employer. The law seeks to protect both the employer and the employe to the full extent of the rightfulness of the ownership of a patent.

Patent Royalties. See Royalties on Patents.

Patterns. A pattern of the type used in producing castings, is a model or form from which a mold can be made in damp sand or other suitable material. This mold when filled with molten metal gives the proper shape to the required casting. The exterior form of an ordinary pattern corresponds to the shape of the casting to be produced, but if holes or interior passages are required in the casting, the pattern is provided with projecting core prints which will give it a different appearance from the casting which is reproduced in the mold. Materials for making patterns include wood, metal, and plaster.

One-piece Patterns: The solid pattern is the simplest type. The term means that the pattern is in one piece, but it may be constructed of several pieces of wood which are fastened together permanently.

Parted or Split Patterns: Most patterns are formed of two parts or sections which are kept in the proper relation to each other by dowel-pins or plates, and are known as *two-part patterns.* In making a mold from such a pattern, one-half of the pattern is first placed joint side down on the molding board so that, after the drag is "rammed up," this joint is flush with the parting line of the mold. The other half of the pattern is then placed in position, preparatory to ramming up the cope. The two-part construction enables the molder to locate the parting line accurately and with less work than is necessary when using a solid pattern. A *three-part pattern* is constructed for molding in a flask with three sections or parts.

Sectional Patterns: It is often possible to make a part or section of a pattern which can be used by the molder, instead of supplying a complete pattern. This is common practice in making molds for circular work where but few castings are required. Rings of almost any section are frequently made by this method. The molder rams up a section of the mold and then moves the section of the pattern to the next position.

Skeleton Patterns: Skeleton patterns are a framework the general outline of which conforms to that of the required casting. The spaces between the framework are filled by the molder with the molding material and are smoothed off to complete the pattern.

Shell Patterns: Patterns of the shell type are used for making drainage fittings of all kinds. They are usually made of iron and are complete models of the finished casting.

Gated Patterns: Gated patterns are small patterns fastened to the runners and gate pin to form a multiple pattern which can be used to mold a number of pieces at one time. The pattern-

maker is sometimes required to make wood patterns on a gate, but more often he furnishes but a single pattern from which the molder casts the required number of patterns and then proceeds to mold and cast them on a gate. This gated metal pattern is then sent back to the shop to be finished smooth. See Draft on Patterns; Joints used in Patternmaking; Match-plate Patterns.

Pattern Shrinkage Allowances. The shrinkage allowances ordinarily made on patterns to compensate for the contraction of castings in cooling are as follows: Cast iron, from 3/32 to ⅛ inch per foot; common brass, 3/16 inch per foot; yellow brass, 7/32 inch per foot; bronze, 5/32 inch per foot; aluminum, from ⅛ to 5/32 inch per foot; magnesium from ⅛ to 11/64 inch per foot; and steel casting, 3/16 inch per foot. The amount of shrinkage, in any case, depends to some extent upon the shape and size of the casting. A plain casting that is long in proportion to its width will contract differently from one that is more compact, even though both castings have the same weight and were cast from the same material. A heavy iron casting may shrink only 1/10 inch per foot or even less, whereas a lighter casting of the same material may shrink ⅛ inch per foot. A cylindrical or column-shaped casting will contract more in a lengthwise direction than radially. Hence, when making patterns for rather large castings of this kind, the allowance should be about 1/10 inch lengthwise and from 1/20 to 1/16 inch per foot radially. For pipes or other hollow castings, the lateral shrinkage is very much less than for solid castings or those having thick walls. A general rule for columns of comparatively small diameter but great length, such as are used for building purposes, is to allow ⅛ inch per foot for shrinkage lengthwise and make no allowance on the diameter. The "one-tenth" shrinkage rule is the standard (for cast iron) in most machine pattern-shops. Although this is not the proper allowance for all forms of casting, the adoption of a standard eliminates the confusion that would follow the use of a number of rules for different classes of work. There is no fixed rule governing shrinkage allowance.

Patterns, Lacquering. Although it is general practice to apply several coats of shellac to wood patterns in order to keep out moisture and protect the glued joints, at least one prominent manufacturer has had very successful results in using lacquer instead of shellac. The advantages cited are that lacquered patterns draw from the sand much better, there is less tearing of the mold and smoother castings are obtained. Experiments have shown that the brushing lacquer is more satisfactory than a spraying lacquer, as the former fills rough places in the pattern more evenly. Wax fillets should be shellacked before applying lacquer,

as otherwise the lacquer will not harden properly over the fillets and sticks to the molding sand. Metal plates and patterns which have not been sherardized may be protected from corrosion by the lacquer coating. The first cost of finishing a pattern with lacquer is greater than when shellac is used, but it is claimed a great many more castings can be obtained from a lacquer finished pattern than from a shellacked pattern before recoating is necessary.

Patterns, Metal. Metal patterns are especially adapted to molding machine practice, owing to their durability and superiority in retaining the required shape. The original master pattern is generally made of wood, the casting obtained from the wood pattern being finished to make the metal pattern. The materials commonly used are brass, cast iron, aluminum and steel. Brass patterns should have a rather large percentage of tin, as this gives a good surface for the casting. Cast iron is generally used for patterns of large size, as it is cheaper than brass and more durable. Cast-iron patterns are largely used on molding machines. Aluminum patterns are light, but they shrink considerably. White metal is sometimes used when it is necessary to avoid shrinkage. The gates for the mold may be cast or made of sheet brass. Some patterns are made of vulcanized rubber, especially for light match-board work. In making master patterns of wood, two shrinkages must be allowed, and, in some cases, a double allowance for finishing. If the pattern is to be of iron for an iron casting, two cast-iron shrinkages must be allowed for, but if the pattern is to be cast iron and the casting of brass, one cast iron and one brass shrinkage will be necessary.

Patterns, Right- and Left-Hand. Many patterns are required in pairs, and when it is not possible to reverse them, and have the centers of hubs, bosses, etc., opposite and in line, they must be made right- and left-hand. If the pattern is a small one or if a great many castings are to be made from it, the better way would be to make two patterns, but if the pattern is large or if only one or two castings are required, the work should be laid out and planned so that the required pieces may be moved from side to side or from end to end in order to change the pattern from right- to left-hand.

Patterns, Standard Colors. Standard colors for painting patterns, adopted by a joint committee on pattern equipment standardization consisting of official representatives from the American Foundrymen's Association affiliated with eight other national organizations are as follows: 1. Surfaces to be left unfinished are to be painted black; 2. Surfaces to be machined are to be painted red; 3. Seats of and for loose pieces are to be red stripes on a yellow background; 4. Core-prints and seats for loose

core-prints are to be painted yellow; 5. Stop-offs are to be indicated by diagonal black stripes on a yellow base.

Patterns, Varnish or Shellac. A yellow or orange shellac varnish is generally used as a protective coating for pattern work, although there are other varnishes, such as copal, etc., that are used in special cases. Shellac comes in thin, flaky irregularly shaped pieces. It is brown in color and can only be cut with alcohol; grain alcohol is best, but wood or denatured alcohol is most frequently used, on account of the high cost of grain alcohol. Core prints and core outlines on the drag part of the pattern are colored, and also surfaces concealed by loose pieces. There is no generally accepted standard for pattern coloring.

Black Shellac: Black shellac is made by adding lampblack to orange shellac. The lampblack should be of good quality and free from grit.

Red Shellac: A good grade of finely ground vermillion mixed with orange shellac may be used for making red shellac. All coloring matter should be ground dry.

Shellac dries quickly and is not easily affected by heat or moisture—two qualities which make it particularly desirable for finishing pattern work. It is also easy to cut through, which is another important consideration when patterns are to be altered. Pots for holding clear or yellow shellac should be of glass or earthenware, as the chemical action set up by the use of a metal pot will darken the shellac. See Patterns, Lacquering.

Pattern Wood. Woods commonly used for patterns are white pine, mahogany, cherry, maple, birch, white wood, and fir. For most patterns, white pine is considered superior because it is easily worked, readily takes glue and varnish, and is fairly durable. For medium- and small-sized patterns, especially if they are to be extensively used, a harder wood is preferable. Mahogany is often used for patterns of this class, although many prefer cherry. As mahogany has a close grain, it is not as susceptible to atmospheric changes as a wood of coarser grain. Mahogany is superior in this respect to cherry, but is more expensive. In selecting cherry, never use young timber. Maple and birch are employed quite extensively, especially for turned parts, as they take a good finish. White wood is sometimes substituted for pine, but it is inferior to the latter in being more susceptible to atmospheric changes. The Honduras mahogany or bay-wood is used for patternmaking, as it is much softer and easier to work than the mahogany used for making furniture, etc. Bay-wood is obtained near the Gulf of Campeche. It is worked almost as easily as pine and can be obtained in long and clear lengths, remark-

ably free from serious defects. The wood is of an open grain and requires careful finishing in order to obtain a smooth surface.

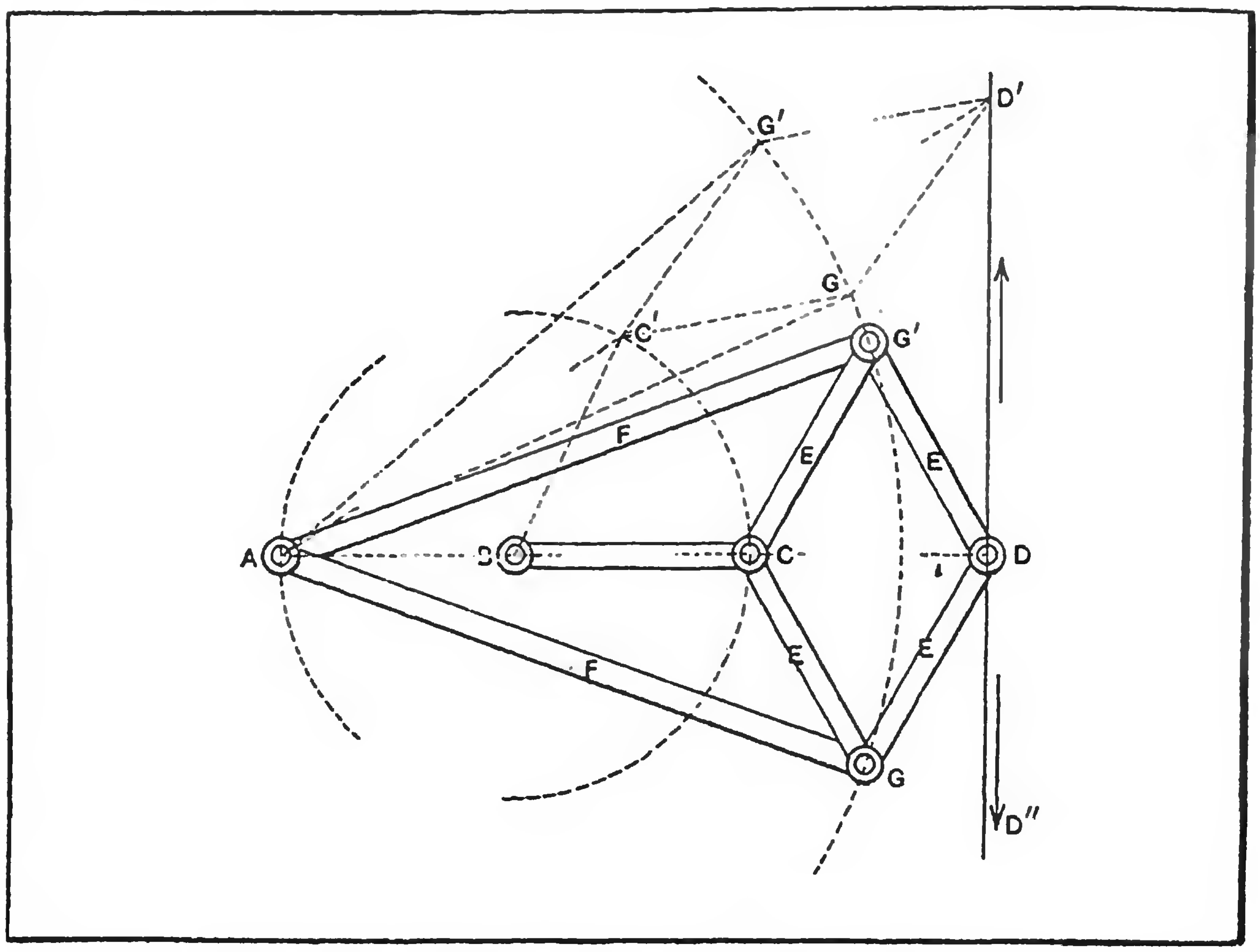
Pawl. That hinged piece in a ratchet mechanism that prevents the ratchet wheel from reversing.

Pea Coal. Pea coal is small coal of such size that the pieces will not pass a screen of ½-inch mesh, but pass a screen of ¾-inch mesh. Pea coal is often used for power plant purposes.

Pearlite. Pearlite is a structural condition present in steel heated beyond the critical temperature and slowly cooled. If the steel that is thus slowly cooled contains very nearly 0.90 per cent of carbon, it will consist of pearlite alone. If it contains more than 0.90 per cent of carbon, it consists of pearlite and microscopic crystals of cementite, and if it contains less than 0.90 per cent of carbon, it consists of pearlite and microscopic crystals of ferrite. Chemically, pearlite is composed of 86.5 per cent of ferrite and 13.5 per cent of cementite.

Peat. Peat consists of decayed vegetable matter and earth, and is found in bogs and swamps. It is cut out and dried, and sometimes pulverized and compressed into blocks before burning. It gives an intense heat, burning with a short blue flame which changes to yellow when the grate spaces become filled with embers. One pound of air-dried peat contains about 7700 B.T.U. Peat briquettes have been used to some extent, and with fair success, in Northern Europe, both under stationary boilers and in locomotives, but, up to the present time, peat has not been employed commercially in the United States, for that purpose. It has been used successfully, however, to some extent in gas producers.

Peaucellier Straight-Line Motion. This motion (see diagram) is the invention of Peaucellier, an officer of the French army. The value of the mechanism in guiding a moving piece along a rectilinear path was at once apparent to the mechanical engineer, but it was reserved for the mathematician to discover the underlying principles of this combination of links. The Peaucellier linkage is composed of seven links moving about two fixed centers of motion, A and B. The four equal links E form a rhombus; the links F are equal; and the center B is midway between A and C. If the point D be moved in the direction of the arrows, it is a simple demonstration in geometry to prove that it will be constrained to move in the straight path $D'D''$, which is perpendicular to the line of centers $ABCD$. This may be tested experimentally. The locus of the point C is the circumference $AC'C$; and the locus of G and G' is the arc described



Peaucellier Linkage for Straight Line Motion

with the radius F. If the center-line of the angle formed by links E and F be in any position, such as $AC'D'$, it will be found that the rhombus the sides of which represent the length of the links E takes the position shown in the drawing.

Peening Metal. When one side of a bar, rod, or plate is hammered, in order to expand or stretch the metal by indenting and compressing it, this is known as *peening*. The ball-peen hammer, which is the type commonly used by machinists, has a ball or spherical-shaped end that is adapted for peening or riveting operations. For peening some parts, the straight indentations left by the straight peen or cross-peen hammers are preferable to the spherical depressions formed by a ball-peen hammer. Peening is frequently done in order to straighten a shaft or bar by stretching the metal on the concave side. The extent to which the metal is expanded or stretched depends upon the area of the surface peened and the force of the peening blows. Some pumps have brass linings which are composed of staves or cast strips that are peened all over in order to secure a tight fit in the cylinder. The edges of these strips are first planed so that a fairly good fit is obtained before peening. After the peening operation, which not only tightens the strips but closes the lengthwise joints between them, the cylinder is bored. The inner sides of worn

piston rings are sometimes peened in order to enlarge the ring and increase its bearing pressure against the cylinder wall.

Peening Piston Rings. Concentric piston rings for internal combustion engines are peened on the inside by some manufacturers, in order to secure a ring which bears against the cylinder wall with practically a uniform pressure around the entire circumference, and a more durable and elastic ring, as the result of the hard compact surface formed on the inside by the peening process. This peening was formerly done by hand and was found to be a rather expensive item in the manufacture of the rings; moreover, the peening was, in most cases, poorly done because of the difficulty in delivering blows of the required intensity when peening rings by hand, which resulted in a ring that did not have the desired resiliency or tension. Since the introduction of the automatic peening machine it is possible to peen rings mechanically and at the same time regulate the peening action.

Peins. The tools used in cold-riveting machines are commonly called peins. Peins used for riveting operations are of many kinds—cup peins; two-, three-, four-, and six-prong peins; pilot peins; serrated-face peins; convex and concave peins; as well as peins for round-head, cone-head, flat-head, pin-head or countersunk-head rivets. Since the pein in the high-speed type of vibratory riveting machine is positively rotated as it hammers, a two-prong concave pein may be the proper tool for a round-head rivet; and if it is desired to expand the rivet in the hole, a wider land is incorporated in the tool than would be the case if only a head were required, as, for example, in a hinged part. This principle applies in varying degrees, according to whether the pein has two, four, or six prongs. Selection of the proper steel and its correct heat-treatment for riveting peins is a matter requiring considerable experience. Peins must be tough enough to withstand tremendous shocks, and at the same time, hard enough to give maximum wear.

Pendulum. A *simple* pendulum is a material point which is supposed to be suspended from a fixed point by a string without weight. A *compound* pendulum is a material body suspended from a fixed axis about which it oscillates by the force of gravity. A *conical* pendulum is formed by a weight suspended by a cord and revolving at a uniform speed along the circumference of a circle in a horizontal plane. The application of the compound pendulum is found in all pendulum clocks. The principle of the conical pendulum is employed in the design of fly-ball governors.

Pendulum Hardness Tester. This is an instrument for testing the hardness of substances from lead to sapphires. It consists

of a frame which is supported on the work by a ruby or steel ball, and may be oscillated like a pendulum. There is a curved spirit level at the top of the frame and a scale that permits of observing accurately the distance traveled by the bubble in the level when the frame oscillates. The hardness of a metal may be determined in two ways; first, by observing the distance that the bubble moves from the zero graduation on the scale with the first oscillation of the pendulum, and second, by ascertaining the length of time elapsed while the pendulum swings ten times. When placed to oscillate on plate glass, the bubble travels from 0 to 97 on the scale; in the first oscillation of the tester, however, on a less hard surface, such as on hardened steel, the ball will indent the surface slightly and elongate this indentation as the pendulum swings. The energy consumed in thus displacing the metal is taken from the potential energy of the pendulum, as is shown by shortening its first swing. The position of the bubble on the scale at the end of the first swing indicates the work done by the ball on the specimen, and is a measure of its hardness. In the case of a soft specimen, the indentation is relatively deep, and the pendulum comes to rest after a short swing; on lead it will not swing at all, so the bubble remains at zero. Typical scale-test readings with a steel ball are as follows: Glass, 97; very hard carbon steel, 93; hard carbon steel, 88; tempered high speed steel, 75; annealed high-speed steel, 54; annealed carbon steel, 41; rolled brass, 14; cast brass, 4; and lead, 0. In making a time test, the hardness number is the time in seconds consumed in making ten single swings. The pendulum is placed gently on the specimen with the bubble at or near 50 and caused to oscillate through a small arc.

Pentabasic Acid. In chemistry, this is an acid which has five atoms of hydrogen in each molecule replaceable by a metal.

Pentagon. A pentagon is a plane figure or surface bounded by five straight lines. If the five lines are of equal length and the angles between the sides are equal, the figure is known as a *regular pentagon.* The angles between the sides of a regular pentagon are 108 degrees.

Pentavalent. Pentavalent, also known as quinquevalent, is a term used to indicate that an atom of one element will combine with five atoms of another element.

Percentage. The per cent of gain or loss is found by dividing the amount of gain or loss by the *original* number on which the percentage is to be based, and multiplying the quotient by 100. For example: Out of a total output of 280 castings a day, 30 castings are, on an average, rejected. What is the percentage of bad castings?

$$\frac{30}{280} \times 100 = 10.7 \text{ per cent.}$$

If by a new process 100 pieces can be made in the same time as 60 could formerly be made, what is the gain in output of the new process over the old, expressed in per cent?

Original number, 60; gain 100 — 60 = 40. Hence,

$$\frac{40}{60} \times 100 = 66.7 \text{ per cent.}$$

Care should be taken always to use the *original* number, or the number of which the percentage is wanted, as the divisor in all percentage calculations. In the example just given, it is the percentage of gain over the old output 60 that is wanted, and not the percentage with relation to the new output 100. Mistakes are often made by overlooking this important point.

Perch. One perch equals 16½ feet, one rod or one pole. A perch of stone is 16½ feet long, 1 foot high and 1½ feet wide, and it contains 24¾ cubic feet.

Percussion Press. A percussion press is a friction-driven type of press used for hot-pressing brass and steel parts and by jewelry and other metal goods manufacturers for work similar to that done with a drop-press. An important feature claimed for percussion presses is the cumulative blow delivered, all the energy of the flywheel being utilized as it comes to a dead stop. See Hot-pressed Brass Parts; Hot-pressed Steel Parts.

Percussive Electric Welding. Percussive electric welding differs from the Thomson or incandescent process in that the heating of the parts to be welded is done instantly by the sudden discharge of a heavy electric current from a condenser at the same moment as the two parts are forced together with a rapid blow. Hence, the resistance to the sudden rush of current momentarily melts the portions of the work that are to be joined at the very moment when they are suddenly forced together, so that a very intimate joint is formed. The process is applied mainly to the welding of wires of the same or dissimilar metals, and can also be used for the welding of a wire to an object of large dimensions.

Perforating Dies. The dies used for punching large numbers of holes or perforations in sheet metal, for producing strainers, sifting devices, etc., and also the dies used for cutting ornamental shapes around the edges of lamp-burner shells or galleries, etc., are commonly known as *perforating dies.* The type of die used

for perforating sheet stock is, in reality, a multiple or gang die, but, as a general rule, the work of a perforating die differs from a gang die in that it is used to punch a large number of holes, whereas a gang or multiple die, as these names are ordinarily applied, means the type that is used to blank out a number of duplicate parts, punch rows of rivet holes, etc. There may be exceptions, however, to this general classification. Some perforating dies, such as are used for perforating sheet metal or other materials, have hundreds of punches which are arranged in rows and operate simultaneously.

Perforating Presses. Presses of this class are used for punching large numbers of small holes in sheet metal, for producing strainers, sieving devices, etc., and also for perforating the sides of circular parts, such as lamp-burner galleries, etc. The perforating of shells and flat sheets is done either in presses of ordinary construction fitted with special attachments or feeding mechanism, or by means of special perforating presses. For perforating heavy sheets or where the quantity required is so small that it is not economical to make a die covering the entire width of a sheet, a special type of press has been developed. This has a sliding table which automatically feeds the stock through the die. The latter may only have one punch or it may be equipped with a gang of punches, the type depending upon the design or quantity of perforating necessary.

Periodic Current. A periodic current is an oscillating current, the values of which recur for equal increments of time. An oscillating current is a current which alternatingly increases and decreases in magnitude with respect to time. See also Electric Currents.

Periodic Law. In chemistry, this law is usually stated as follows: "The properties of the elements are periodic functions of their atomic weights." If the chemical elements are arranged in the order of their atomic weights, there will be found at regular intervals of the series, elements that have similar physical and chemical properties; that is, there is a periodic recurrence of similar properties. If these elements are arranged by themselves in order, they form a group. The modern classification of the chemical elements is generally based upon these groups rather than upon the older methods of distinguishing between metals, metalloids, and non-metals.

Periphery. The periphery is the curved line which forms the boundary line of a circle (circumference), ellipse, or similar figure.

Permanent Hardness. This is a condition in boiler feed water which is due to the presence in the water of sulphates, chlorides, and nitrates of lime and magnesia. As these are not precipitated until a temperature of 300 degrees F., or more, has been reached, water containing these impurities is known as permanently hard.

Permanent Mold. This is a mold for making castings, which is made of metal and, hence, is of a comparatively permanent nature. A metal mold can be used for a large number of castings while a sand mold disintegrates for each casting made.

Permanent Set. When external forces act upon a material, they tend to produce stresses in it. All stresses to which a material is subjected cause a deformation. If the stresses are not too great the material will return to original shape upon removal of the external force. If however, the stresses are too great, the elastic limit of the material will be exceeded and the material will not return to its original shape upon removal of the load. This deformation is known as permanent set or plastic deformation.

Permeability. Permeability may be defined as the conductivity of substances for magnetic lines of force. Free space is taken as unity of permeability. The number of lines of force passing through different substances of the same length and cross-section is proportional to their respective permeabilities. The reciprocal of permeability is *reluctivity* (not to be confused with reluctance). The permeability is sometimes, therefore, also defined as the reciprocal of the magnetic reluctivity. Any material which has a magnetic permeability greater than that of a vacuum is known as a *paramagnetic* substance; and any material which has a permeability less than that of a vacuum is known as a *diamagnetic* substance. The materials which are strongly paramagnetic, sometimes designated as *ferromagnetic* to distinguish them from materials which are only slightly paramagnetic, are iron, steel, nickel, cobalt, and certain alloys. Bismuth is distinctly diamagnetic. All other materials may be classed, generally, as non-magnetic. Their permeability differs from unity by less than 1 per cent.

Permeameter. The permeameter is an instrument for measuring the permeability of a piece of iron or steel with sufficient accuracy for commercial purposes, or for determining the mechanical properties of iron and steel by ascertaining the corresponding magnetic characteristics. In one form in which this instrument is built, the permeability is indicated by the magnitude of the mechanical force required to detach one end of the sample,

arranged as the core of a straight electromagnet, from an iron yoke. The permeability is calculated when the value of this force is known. More common is the method which employs a ballistic galvanometer to measure the magnetic induction produced in a sample and the magnetizing force producing it, from which the permeability can be determined. See also Magnetic-mechanical Analysis.

Permutations and Combinations. In algebra the number of *permutations* that can be made of different elements or symbols is the number of different ways in which they can be arranged in successive order. Thus, the letters *ab* have two permutations which are *ab* and *ba*. When there are three terms such as *a*, *b* and *c*, the number of permutations possible is six. This may be determined as follows: the letter *a* may be in any of three positions. For each position that *a* is in, the letter *b* may be in one of two positions. The possible arrangements or permutations of *a* and *b* in this three-letter combination are $3 \times 2 = 6$. Now for each position that *a* and *b* may be in there is only one remaining position for *c*. Hence, the number of permutations of a three-letter combination is $3 \times 2 \times 1 = 6$. For a four-letter combination it would be $4 \times 3 \times 2 \times 1 = 24$. For a combination of n terms it would be $n(n\text{-}1)\ (n\text{-}2) \ldots\ldots 1$ or as it is commonly expressed $n!$ or n factorial. Where some of the given elements or symbols are alike or where only a part of them are to be rearranged each time, formulas are used which take these conditions into account.

In algebra the number of *combinations* is the number of different groups of a given numerical size that can be made up from a larger group of different elements, regardless of their order. Thus, suppose it were to be determined how many different groups or combinations of three each could be made up from a group of six different elements. This may be determined as follows: If one element is selected from a group of six, there are ten possible pairs that might be selected from the remaining five elements to go with it to make up a group of three. If we now set this one element to one side and select another, there would be six possible pairs that might be selected from the remaining four elements to go with it to make up a group of three. Setting the second element aside and selecting a third, there would be three possible pairs that might be selected from the remaining three to go with it to make up a group of three and finally if this third element is set aside there is one group of three remaining. The number of possible combinations of three each that can be selected from a group of six is, therefore, $10 + 6 + 3 + 1 = 20$. Written algebraically, a formula for the number of combinations of elements which can be taken from a group of elements, all different, where

n equals the number of elements in each combination, N equals the number of elements in the group and C equals the number of combinations, would be $C = \frac{N!}{n!\,(N-n)!}$ which is in effect a different way of arriving at the same answer. For the specific example just given $n = 3$ and $N = 6$ so that $C = \frac{6!}{3!\,(6-3)!}$

$$= \frac{6 \times 5 \times 4 \times 3 \times 2 \times 1}{(3 \times 2 \times 1)\ (3 \times 2 \times 1)} = 20.$$

Other similar formulas which are given in treatises on algebra enable the determination of special types of permutations and combinations.

Perpetual Motion. The numerous attempts to invent a machine capable of "perpetual motion" have failed because the successful operation of such a machine would require the creation of energy. According to the principle of work (neglecting frictional or other losses) the applied force, multiplied by the distance through which it moves, equals the resistance overcome, multiplied by the distance through which it is overcome. That is, a force acting through a given distance can be made to overcome a greater force acting as a resistance through a less distance; but no possible arrangement can be made to overcome a greater force through the same distance. The principle of work may also be stated as follows:

Work put into machine = lost work + work done by machine.

This principle holds absolutely true in every case. It applies equally to a simple lever, the most complex mechanism, or to a so-called "perpetual motion" machine. No machine can be made to perform work unless a somewhat greater amount—enough to make up for the losses — be applied by some external agent. As in the "perpetual motion" machine no such outside force is supposed to be applied, this problem is absolutely impossible, and against all the laws of mechanics.

Perspective Drawing. A perspective drawing may be defined as a representation upon a plane surface of the appearance of an object as seen by the eye from some given point of view. Perspective projection, therefore, differs from orthographic projection, as used in ordinary mechanical drawing, in that it represents the whole object in one view, showing its appearance as seen by the eye, but not showing the true relationship between the dimensions, nor showing the dimensions to any true scale. Oblique or isometric projection is also used, to some extent, to represent an object as it appears to the eye, but in these two latter types of projection the lines are drawn to some predetermined scale, so

that an isometric or oblique projection may be said to form a step between the ordinary mechanical drawing and the true perspective.

Petroleum. Carbon and hydrogen in chemical combinations known as hydrocarbons form the main elements in petroleum and frequently there is in addition, relatively small amounts of oxygen, nitrogen and sulphur. The amount of carbon in crude oils usually varies from 80 to 89 per cent and the hydrogen from 10 to 15 per cent. The oxygen may vary from zero up to 5 per cent; the nitrogen from zero up to 1.8 per cent; and the sulphur, from 0.01 to 5 per cent.

Petroleum or "crude oil" is an inflammable mixture and is found in subterranean deposits which are tapped by drilling and may be located hundreds or even thousands of feet below the surface of the earth. There are three general classes of petroleum which may be defined respectively as paraffin-base, which contains solid paraffin hydrocarbons and practically no asphalt; asphalt-base, containing asphalt and no paraffin; and paraffin-asphalt, which is a combination of these elements. The paraffin-base petroleum usually is of lightest gravity and yields the largest variety of lubricating oils. Although petroleum is sometimes used in the crude state for fuel or for surfacing roads and to lay dust on roads, the various motor fuel oils and lubricating oils, etc., are obtained by different distilling and refining processes.

The specific gravity of petroleum varies considerably according to its composition. It may be as low as 0.8 and as high as 1; frequently it is found to be about 0.88. Pure petroleum is composed mainly of hydrocarbons which distill at different temperatures. Some crude oils contain a large percentage of the lighter hydrocarbons, while others are composed principally of lubricating hydrocarbons.

The lightest vapors are driven off at about 115 degrees F., while the heavier vapors and oils require temperatures up to 600 degrees F. The heat value of petroleum varies with its specific gravity and also with the amount of impurities that it contains. California oil of a specific gravity of 0.92 has a heating value of about 19,000 B.T.U. per pound. Caucasian crude oil of a specific gravity of 0.88 has a heating value of 22,000 B.T.U. per pound. As a general average, the heating value of crude oil per pound may be assumed to be from 19,000 to 20,000 B.T.U.

Topped Crude Petroleum: A residual product remaining after the removal, by distillation, or other artificial means, of an appreciable quantity of the more volatile components of crude petroleum. The term *tops* is applied to the unrefined distillate obtained in topping a crude petroleum.

Weathered Crude Petroleum: The product resulting from crude

petroleum through loss, due to natural causes, during storage and handling, of an appreciable quantity of the more volatile components.

Petroleum Spirits or White Spirits: A refined petroleum distillate with a minimum flash point of 70° F. (21° C.) determined by the Tag Closed Tester in accordance with the standard method of test for flash point of volatile flammable liquids of the American Society for Testing Materials or by the Abel Tester, with volatility and other properties making it suitable as a thinner and solvent in paints, varnishes and similar products. NOTE.—The term "turpentine substitute" as applied to petroleum spirits is false and misleading. The term "mineral spirits" which is frequently used in the paint and varnish industry is a misnomer as it includes within its scope not only petroleum products, but other hydrocarbon mixtures, such as coal-tar distillates. In Great Britain the term "petroleum spirits" is applied to a very light hydrocarbon mixture having a flash point below 32° F. (0° C.).

Petroleum Lubricating Grease: A combination of a petroleum product and a soap or a mixture of soaps, suitable for certain types of lubrication.

Petroleum Naphtha: A generic term applied to refined, partly refined or unrefined petroleum products and liquid products of natural gas, not less than 10 per cent of which distills below 347° F. (175° C.) and not less than 95 per cent of which distills below 464° F. (240° C.), when subjected to distillation in accordance with the standard method of test for distillation of gasoline.

Pewter. The name "pewter" is given to a number of alloys of various metals in which tin is always the chief constituent. Generally, the alloy is composed of tin and lead. Thus, an alloy of 71.5 parts of tin and 27.8 parts of lead, or 78.2 parts of tin and 21.7 parts of lead, together with some impurities, is known as Roman pewter; but practically any composition of tin and lead, in which tin is the chief constituent, is known by the same name.

Phase. The distance, usually in angular measure, of the base of any ordinate of an alternating wave from any chosen point on the time axis, is called the phase of this ordinate with respect to this point. The general term *polyphase* is applied to any system of more than a single phase. This term is ordinarily applied to symmetrical systems. *Single-phase* is a term characterizing a circuit energized by a single alternating e.m.f. Such a circuit is usually supplied through two wires. The currents in these two wires, counted positively outwards from the source, differ in phase by 180 degrees or a half-cycle. *Three-phase* is a term characterizing the combination of three circuits energized by alternating

e.m.f.'s which differ in phase by one-third of a cycle; i.e., 120 degrees. *Quarter-phase or two-phase* are terms characterizing the combination of two circuits energized by alternating e.m.f.'s which differ in phase by a quarter of a cycle; i.e., 90 degrees. *Six-phase* is a term characterizing the combination of six circuits energized by alternating e.m.f.'s which differ in phase by one-sixth of a cycle; i.e., 60 degrees.

Phase-Advancer. A phase-advancer, also called a "phase-modifier," is an asynchronous machine that supplies reactive volt-amperes for improving the power factor of an induction motor. Induction motors and other inductive apparatus take a component of current that lags behind the line voltage and thereby lowers the power factor of the system, while a non-inductive load, such as incandescent lamps, takes only current in phase with the voltage and operates at unity or 100 per cent power factor. The operating conditions of an installed motor, which has turned out to be too weak, may be improved by a phase-advancer so that the motor is able to conform to heavier service than that for which it was originally designed. The compensating action of the phase-advancer is entirely automatic and it can be so designed that it corrects the power factor of the main motor from about one-third to one and one-half the normal load, to unity or any other desired value, lagging or leading. The phase-advancer is only intended to be used in connection with induction motors that run continuously in one direction, and its most important application is with large slow-speed motors which have inherently a poor power factor, as well as to motors that run most of the time at part load and at a low power factor.

Phase-Converter. According to the American Standard a rotary phase-converter is a machine which converts power from an alternating-current system of one or more phases to an alternating-current system of a different number of phases, but of the same frequency.

Philadelphia Carriage Bolt Thread. This is a screw thread for carriage bolts which is somewhat similar to a square thread, but having rounded corners at the top and bottom. The sides of the thread are inclined to an inclusive angle of 3½ degrees. The width of the thread at the top is 0.53 times the pitch.

Phos-Copper. This is a brazing alloy that melts at approximately 1300 degrees F. It possesses high tensile strength and excellent penetration, is self-fluxing for most applications, has high ductility, high resistance to fatigue and corrosion, high electrical conductivity, and unusual fluidity at the brazing temperature. It is suitable for use in place of expensive silver solders and is particularly useful for applications where strength or gas-

and liquid-tight joints are required. Phos-copper is used on refrigerator parts where leakproof joints are essential.

Phosphor-Bronze. Copper is the chief element in phosphor-bronze; the other ingredients are tin and phosphorus with small percentages of zinc, iron, and lead. This metal is an excellent composition for use where anti-friction qualities are desired, standing up exceedingly well under heavy loads and severe usage. Phosphor-bronze resists corrosion to a considerable extent, and is, therefore, used for parts that are exposed to the action of salt water.

Phosphor-bronze according to S.A.E. specification No. 64 is composed as follows: Copper, 78.0 to 82.0 per cent; tin, 9.00 to 11.00 per cent; lead, 8.00 to 11.00 per cent; phosphorus, 0.25 per cent; zinc, 0.75 per cent; nickel 0.50; antimony 0.50; phosphorus 0.25 per cent. Good castings made of this alloy should give the following minima in physical characteristics: Ultimate strength, 25,000 pounds per square inch; yield point, 12,000 pounds per square inch; elongation in two inches or proportionate gage length, 8 per cent.

Phosphor gear-bronze according to S.A.E. specification No. 65 is composed as follows: Copper, 88 to 90 per cent; tin, 10 to 12 per cent; phosphorus, 0.10 to 0.30 per cent; lead, zinc and other impurities, maximum, 0.50 per cent. Good castings made of this alloy should give the following minima in physical characteristics: Ultimate strength, 35,000 pounds per square inch; yield point, 20,000 pounds per square inch; elongation in two inches by proportionate gage length, 10 per cent. This is a very hard bronze and may be used for gears and worm-wheels subjected to severe service.

Electrical Applications: Phosphor-bronze has properties making it ideally suited for various electrical applications. It is non-magnetic, so can be used in many cases where steel is out of question, and when used for springs, its corrosion resistance is better than that of the usual spring steel. It can be drilled, stamped, and otherwise machined without necessity of heat treatment, and can be soldered or brazed with ease. The electrical and physical properties vary with the tin content—the higher the tin content, the lower the conductivity and the harder the alloy.

Phosphor-Bronze Springs. Brass and phosphor-bronze should be used for springs that must resist moisture. These springs are more expensive than steel springs, both on account of the higher cost of the material, and because the permissible stress is less, thus making larger sizes of these springs necessary for the same capacity. If a spring of a material other than steel is desired, phosphor-bronze is usually specified. If the mixture is right, such

a spring cannot be surpassed by anything except steel. When difficulties are met with in the use of phosphor-bronze springs, it is advisable to ascertain whether the troubles are not caused by the absence of the necessary amount of tin, or the presence of too much zinc. A phosphor-bronze wire intended primarily for springs has the following composition: Tin, 4 to 6 per cent; phosphorous, 0.03 to 0.04 per cent; zinc, maximum, 0.2 per cent; iron, maximum, 0.1 per cent; lead, maximum, 0.1 per cent; copper, the remainder. See Spring Brass and Bronze.

Phosphor-Copper. This is an alloy of phosphorus and copper containing up to 15 per cent of phosphorus, and used in the making of phosphor-bronze, the phosphorus being introduced into this bronze in the form of phosphor-copper.

Phosphor Gear-Bronze. This is an alloy of copper and tin of the phosphor-bronze class. For S.A.E. specification No. 65, see Phosphor-bronze.

Phosphor-Tin. This is an alloy of phosphorus and tin containing up to 5 per cent of phosphorus, and used in the making of phosphor-bronze, the phosphorus being introduced into this bronze in the form of phosphor-tin.

Phosphorus. Phosphorus is one of the non-metallic chemical elements, the symbol of which is *P*, and the atomic weight, 31.04. Perfectly pure phosphorus is white and transparent, having the solidity of wax. It is usually, however, yellow in color, due to the presence of allotropic "red phosphorus." The specific gravity of phosphorus is about 1.82 at 32 degrees F. It melts at 44 degrees C. (111 degrees F.), when the specific gravity drops to 1.76. It boils at 290 degrees C. (554 degrees F.). Phosphorus is highly inflammable, taking fire in air at a temperature of 34 degrees C. (93 degrees F.). Its specific heat at 32 degrees F. is 0.202. So-called "red phosphorus"—an allotropic form of phosphorus—is produced by heating yellow phosphorus to about 300 degrees C. (about 570 degrees F.) in a closed vessel. Red phosphorus has a specific gravity of 2.25. It melts at about 610 degrees C. (about 1130 degrees F.). Its specific heat equals 0.183. Phosphorus enters as one of the impurities in a great many of the most important iron ores, and is nearly always present in commercial iron and steel. Its presence above a certain percentage is always detrimental to the quality of the steel, and various metallurgical processes are used for the purpose of reducing the phosphorus contents as much as possible.

Photomicrography. Photomicrography is the science of photography under high-power microscopes. With a photomicrograph a piece of steel has been enlarged and photographed 15,500 diameters in a single projection. Such magnification is so tremendous

that only objects invisible to the naked eye can be dealt with in order to be able to get the enlarged image on a photographic plate. This same combination of lenses is capable of separating and photographing lines lying so close together that 200,000 of them are contained within a single inch. The apparatus used in carrying out this work, a Leitz micro-metallograph, consists essentially of a very high power microscope arranged between a powerful automatic arc light and an extremely fine camera, the entire apparatus being mounted on a carriage suspended on sensitive springs so that even a slight movement of the floor will not disturb it. See Metallography.

Phototubes. See Electronic Tubes; Electronic Tubes, Industrial Applications and Electronic Tubes, Industrial Types.

Pi (π). The Greek letter π is used to denote the ratio of the circumference of a circle to its diameter; hence, it is a number constant for all circles. It cannot, however, be expressed by an exact arithmetical figure, because it is an incommensurable number—that is, a number having an infinite number of decimals. The ratio has been calculated to as many as 707 decimals; this was done by Shanks, in 1873. The first twenty-five decimals are as follows:

3.1415926535897932384626434.

For practical use, the first four decimals only are required. As the fifth decimal is "9," the fourth decimal is raised to "6" when only four decimals are used; hence, π, for ordinary calculations, is almost always assumed to equal 3.1416. Fractional approximations that give very close results are to assume π equal to 22/7 or 355/113.

Piano Wire. Piano wire, also known as *music wire,* is a high grade of steel wire. It has an ultimate strength of from 300,000 to 340,000 pounds per square inch, the wire being drawn in comparatively small sizes only.

Pickling Castings. Castings are "pickled" or immersed in an acid bath in order to soften and remove the sand and scale on the surface of the castings, so as to make it easier to machine them and reduce the wear of tools and the time required for their resharpening and resetting. The pickling solutions used for removing scale from castings and forgings preparatory to milling or other machining operations are usually composed either of dilute sulphuric acid, oil of vitriol, or hydrofluoric acid. Iron castings are usually pickled with sulphuric acid. The sulphuric acid pickling solution is generally made up of one part of sulphuric acid to from four to ten parts of water. The sulphuric acid should always be poured into the water while the latter is being stirred. The reason for this is that a chemical reaction

takes place which causes the bath to become quite warm, but there is no dangerous ebullition if properly mixed. However, if the water is poured upon the sulphuric acid, the latter, being much heavier than water, remains at the bottom. When an attempt is made to stir the solution, the water enters the acid in small streams, and is instantly raised to the boiling point, generating steam, which may cause an explosion.

Picric Acid. Picric acid, chemically, is similar to nitroglycerine, in that it is a trinitro-phenol, whereas nitroglycerine is a trinitro-glycerine. Picric acid is a powerful explosive with a very high melting point; so high, in fact, that it must be adulterated to bring its melting point down in order to make it of practical value. It is one of the most dangerous explosives to handle or manufacture. Phenol, from which picric acid is made, is the chemical name for what is commonly known as carbolic acid.

Piezometer. The piezometer is an instrument of meter used for determining the pressure in a pipe containing water or other fluid. It consists simply of a vertical tube inserted into a pipe containing fluid under pressure. The fluid will then rise in the tube, and the vertical height to which it rises will be equal to the head producing the pressure at the point where the tube is inserted. The instrument is sometimes used for determining the location of obstructions in pipe mains. If the observed pressure at any one point falls below what would be expected under normal conditions, there is an obstruction between this point and the water reservoir. If the pressure recorded by the piezometer is higher than normal, it shows that the pressure at this point has been increased by an obstruction beyond the point where the instrument is located.

Pig Iron. Pig iron, which is a product of the blast furnace, is obtained directly from iron ore, and is the raw material used in the production of all kinds of iron and steel. The term "pig" is derived from the original method of casting the bars of pig iron in depressions or molds formed in a sand floor adjacent to the blast furnace. The molds in the pig bed were connected to a runner or feeder (known as the "sow"), and, when filled with metal, this runner and the numerous smaller molds were supposed to resemble a litter of sucking pigs; hence, the name "pig iron." What is known as *sand cast pig* is produced in this way. *Chill cast pig* is made in metal molds or chills, and *machine cast pig,* in a pig-casting machine. Pig iron is remelted usually in a cupola, for making ordinary castings, and it is converted into steel either by the open-hearth, Bessemer, or crucible processes, and into wrought iron, by the puddling process. Pig iron contains about 93 per cent of pure iron, from 3 to 5 per cent of carbon, and some silicon, manganese, sulphur, and phosphorus.

Grades of Pig Iron: Pig iron may be classified either according to its composition, its intended use, or the method of manufacture. The modern method of grading pig iron is by chemical analysis. The former practice was to examine the fracture of a broken pig. If the silicon is low and the carbon all combined, the fracture is white, whereas, if the silicon is high, the fracture is silvery. If the carbon is in the form of graphite, the fracture is gray. Terms such as "high silicon pig," "low phosphorus pig," etc., are used to indicate an important element in the composition. Pig iron may be classified according to the methods of manufacture, as, for instance, *coke pig,* which is smelted with coke; *charcoal pig,* which is smelted with charcoal; and *anthracite pig,* which is smelted with anthracite coal mixed with coke. The name given a brand or grade of pig iron may also indicate its intended use. For instance, *Bessemer pig* is used for making acid Bessemer and acid open-hearth steel; *basic pig* is used for the basic open-hearth process; *foundry pig,* for general foundry work; *malleable pig,* for making malleable cast-iron castings. The names "iron" and "pig" are often used as abbreviations for pig iron.

Pillar Crane. This is a crane consisting of a column or post supported and pivoted at the foundation, a boom extending from a point near the foundation to the point where the tackle for lifting the load is mounted, and a tie rod which connects this latter point with the top of the column or post. There is no trolley moving horizontally along the arm as in a jib crane, and the load, therefore, is moved in a horizontal direction along the periphery of a circle only, but has no radial movement. The type known as "pillar jib crane," however, is provided with a jib on which a trolley moves, so that the load can be moved both in a radial and circular direction.

Pillar File. This is a style of file that is parallel as to width, but tapers somewhat in thickness toward the point. The cross-section of a pillar file is similar to that of a hand file, except that it is thicker in proportion to the width; these files are made in narrow and extra narrow patterns. They are double-cut and are applicable to general machine shop work, especially in connection with erecting and fitting.

Pilot for Cutting Tools. A pilot for metal-cutting tools, such as boring-bars and reamers, is a cylindrical part which extends beyond the cutting end and enters a close-fitting hole in some rigid member, thus supporting the cutting edges and preventing the lateral deflection that might otherwise occur.

Pilots for Punches. Pilots or guide pins are placed on the ends of some punches for aligning the stock before blanking, by entering holes that have been pierced previously. A pilot should

be made slightly smaller than the hole in the blank and should be straight for the thickness of the stock, and then rounded off similar to the point of an acorn. When pierced holes are very small the punch should be provided with a spring pilot, so that if the pilot misses the pierced hole in the blank, it will spring back into the punch.

Pinion Blank Enlargement. When an ordinary pinion is used (having a pressure angle of 14½ degrees) twelve teeth is generally considered the minimum number if the addendum conforms to the usual standard. Even with a pinion of this size, the flanks of the teeth must be under-cut somewhat to avoid interference, provided the mating gear has more than twelve teeth, and this interference and the need for under-cutting increases if the pinion is to run with larger gears. A method of improving the shape of the pinion tooth that has long been employed consists in enlarging the pinion blank and reducing the gear blank a corresponding amount. Another method is to increase the pressure angle of the gearing, and a third method consists in modifying both the pressure angle and the blank diameters in order to obtain a tooth shape giving the best results. Enlarging the pinion blank and decreasing the gear blank a corresponding amount (if the center distance is to remain the same) is applied not only to spur gears but also to bevel gears, worm-gearing, and herringbone gears. In cutting an enlarged pinion or a reduced gear (whether by hobbing or on a generating shaper or planer) the procedure is the same as for cutting standard gear teeth, and any generating type of machine may be used. The teeth are cut to the full depth on both pinion and gear, and in the usual manner, but if the position of the cutter relative to the gear blank is checked by measuring the tooth thickness, then the change in the height of the pinion and gear addendum must be taken into account, the tooth thickness being measured where the pitch circle crosses the tooth in each case. When the pinion blank is enlarged and the gear blank reduced, without changing the pressure angle, the practical effect is to move the pinion teeth outward radially and the gear teeth inward a corresponding amount relative to the pitch circles as well as to the base circles from which the tooth curves are derived.

Pinion Rod. Many small steel and brass pinions are produced by first making the pinion in rod form, and then cutting the rod into whatever lengths are required for the pinions. The teeth are formed along the rod, which may have a length of three or four feet. The companies making pinion rod usually sell it in rod form, and the manufacturer using the rod cuts it into short pinion lengths. Either a hand screw machine or an automatic is generally used for this purpose, the machine being employed to

cut whatever shoulders, holes, or bearing surfaces are required for the pinion. *Cold-drawn pinion rod* is produced by methods that, in a general way, are practically the same as the methods employed for making cold-drawn rods or other sections. Care has to be exercised in determining the various reductions and annealings, in order to obtain the correct shape of tooth and size of rod, as well as the most suitable temper in the finished rod, for obtaining good cutting qualities.

Pinions, Lantern. See Lantern Pinions.

Pintle Chain. What is known as a "closed end" pintle chain was designed primarily to replace link-belts of corresponding pitch for transmissions requiring greater strength, or where the amount of dirt or grit was such as to interfere with the operation of the "open-book" connection of the link-belt. This "closed end" chain is adapted for elevating or conveying machinery, or for power transmission.

Pipe. Pipes are manufactured from various metals such as steel, cast iron, wrought iron, brass, copper, and lead.

Wrought-iron and Steel Pipe: Wrought-iron and steel pipes are made in different thicknesses. The actual outside diameter is the same, the increased thickness of the wall merely decreasing the internal diameter. The term "wrought-iron pipe" is often used indiscriminately to designate all butt- or lap-welded pipe whether made from wrought iron or steel, but the term *wrought pipe* is preferable for designating either steel or wrought-iron pipe. A large percentage of the wrought pipe now used is made of steel. When wrought-iron pipe is desired the term "genuine wrought iron" or "guaranteed wrought iron" should be used, as otherwise the manufacturer will invariably supply steel pipe.

The size of iron and steel piping is specified in terms of the nominal inside diameter excepting for the large sizes, as noted later. For standard pipe, the actual inside diameter is usually greater than the nominal, especially on the smaller sizes, but in the extra strong, and especially in the double extra strong pipe, the internal diameter is less than the nominal size. The thickness of the wall and the weight per linear foot of piping varies on account of the difficulty in securing uniformity in the process of manufacture. It is assumed to be permissible for standard weight pipe to vary from 5 per cent above to 5 per cent below the standard weight. (See Pipe Schedule Numbers.)

Formerly wrought iron was preferred for the best classes of work, but records of installations and tests have demonstrated that steel pipe is equal to wrought-iron pipe for general work and, according to some authorities, resists corrosion, in the average case, as well as wrought iron; the steel pipe is also cheaper than wrought iron. The term *galvanized iron pipe* is ap-

plied to ordinary wrought pipe which has been galvanized. The abbreviated expression *O. D. pipe* is applied to large wrought pipe, the nominal size of which is designated by the outside diameter instead of the inside diameter as in the case of smaller sizes. It is common practice to designate the nominal sizes of all pipes above 12 inches by giving the outside diameter.

Cast-iron Pipe: Cast-iron pipe is used instead of wrought pipe where the pipes must be placed under ground or submerged, and also for main steam pipes and branches which are subjected to acids. Cast-iron pipe is extensively employed for cold water on lines 4 inches in diameter and above. Commercial cast-iron pipe is unsuitable for lines subjected to expansion strains, contraction, and vibration unless the pipe is very heavy. It is not suitable for superheated steam or for temperatures above 575 degrees F. The cast-iron pipe used for underground work generally has the *bell-and-spigot* ends which are leaded and calked to secure a tight joint. Exposed cast-iron pipes usually have flanged ends See also Brass Pipe.

Pipe and Tube Bending. In bending a pipe or tube, the outer part of the bend is stretched and the inner section compressed, and as the result of opposite and unequal stresses, the pipe or tube tends to flatten or collapse. To prevent such distortion, the common practice is to support the wall of the pipe or tube in some manner during the bending operation. This support may be in the form of a filling material or temporary support that is placed inside the pipe.

Use of Filling Material: A simple method of preventing distortion and one that has been widely utilized, especially when pipe or tube bending is done by hand and on a small scale, consists in using some filling material which is placed inside the pipe to support the walls to prevent flattening at the bend. Dry sand is often used. Other filling materials, such as resin, tar, or lead, are sometimes employed. The pipe is first filled either with molten resin, lead, or some alloy having a low melting point, and then after bending, the pipe is heated sufficiently to melt the filling material. Resin has often been used for bending small brass and copper pipes, and lead or some alloy for small iron and steel pipes. Before bending either copper or brass pipe or tubing, the latter should be annealed.

Alloy of Low Melting Point Used as Filler: Filling of tubes with lead may result in satisfactory bends, but the comparatively high melting point of lead often has a deleterious effect on the physical properties of the tube. A commercial alloy known as "Cerrobend" has a melting point of only 160 degrees F.—considerably less than the temperature of boiling water. "Cerrobend" is composed of bismuth, lead, tin, and cadmium. With this material, tubes having a wall as thin as 0.007 inch have been bent

to small radii. The metal filler conforms to the inside of the tube so closely that the tube can be bent just as though it were a solid rod.

This method has been applied to the bending of copper, brass, duralumin, plain steel, and stainless steel tubes with uniform success. Tubes plated with chromium or nickel can be bent without danger of the plate flaking off. The smallest tube so far bent was 1/8 inch in inside diameter. The practice usually is economical for tubes up to 2 inches in diameter. For larger sizes, the cost of the metal filler would probably be too high on an average job. The method is considered ideal when the number of tubes of a given size or kind is more or less limited or when the bend is especially severe.

When a tube-bending operation has been completed, the removal of the metal filler is a simple process. The tube may be heated in steam, in a bath of boiling water, or in air of about the same temperature; the metal can then be drained out and used again and again.

Mandrel Inside of Tube: For certain classes of pipe and tube bending, some form of internal mandrel is used so that the pipe or tube is supported both externally and internally in order to prevent flattening. Internal mandrels are used particularly in connection with the bending of thin tubing. The mandrel may be in the form of a plain cylindrical bar that fits closely inside the tube and has a rounded end at the bending position, or it may be of special form.

The ball type of mandrel has been used for many tube-bending operations. The ball is so connected to the end of its supporting arbor that it has a limited amount of movement, and partially supports the curved section of the tube. This general type of mandrel has been used both on hand-operated fixtures and on power-driven pipe- and tube-bending machines. In some cases, two or more rounded or spherical-shaped supports are used. These are linked together to provide flexibility at the bend.

Rule for Safe Minimum Radius: Pipes are often bent to avoid the use of fittings, thus eliminating joints, providing a smooth unobstructed passage for fluids, and resulting in certain other advantages. Sometimes it is desirable to make the radius of the bend as small as possible without causing distortion, whereas on other classes of work, the radius may be comparatively large, as, for example, when pipes are curved to provide means of compensating for expansion and contraction in a line of piping.

The safe minimum radius for a given diameter, material, and method of bending depends upon the thickness of the pipe wall, it being possible, for example, to bend extra heavy pipe to a smaller radius than pipe of standard weight. As a general rule,

wrought iron or steel pipe of standard weight may readily be bent to a radius equal to five or six times the nominal pipe diameter. The minimum radius for standard weight pipe should, as a rule, be three and one-half to four times the diameter. It will be understood, however, that the minimum radius may vary considerably, depending upon the type of fixture or machine used for bending. Extra heavy pipe may be bent to radii varying from two and one-half times the diameter for smaller sizes to three and one-half to four times the diameter for larger sizes.

Rules for Finding Lengths of Bends: In determining the required length of a pipe or tube before bending, the lengths of the straight sections are, of course, added to the lengths of the curved sections in order to make the proper allowance for bends. The following rules may be used for finding the lengths of the curved sections.

Rule: To find the length of a 90-degree or right-angle bend, multiply the radius of the bend by 1.57 (the radius is measured to the center of the pipe or to a point midway between the inner and outer walls).

Rule: To find the length of a 180-degree or U bend, multiply the radius of the bend by 3.14.

Example: A right-angle or 90-degree bend is to have a radius of 10 inches and straight sections on each side of the bend of 5 and 15 inches, respectively. Find the total length of the pipe before bending.

Length of curved part $= 1.57 \times 10 = 15.7$ inches; hence, total length $= 15.7 + 5 + 15 = 35.7$ inches.

A general rule for finding the lengths of sections having degrees of curvature other than 90 and 180 is as follows: Multiply the radius of the bend by the included angle, and then multiply the product by the constant 0.01745. The result is the length of the curved section.

To prevent flattening at the ends there should be a straight section adjoining the bend equal at least to the pipe diameter or to 1½ times the diameter for pipes larger than 10 inches.

Bending Tubing for Refrigerating Equipment: The following general methods are employed by a very large manufacturer of brass and copper tubing. Coils of a large variety of shapes are made by this company from tubing as small as 1/16 inch in diameter and as large as 2 inches.

Bending Tubing around a Plain Cylindrical Mandrel: If the diameter of the coil is fairly large relative to the size of the tubing, the coil can be formed on a plain cylindrical mandrel, mounted on the headstock of a lathe. At the beginning of the operation, the tube is slipped over a round-end arbor to prevent it from buckling. This arbor is mounted on a rod that is fastened

to a stand located at a sufficient distance from the lathe to accommodate the length of tubing required for the coil. The forward end of this supporting arbor is above and slightly in advance of the center of the lathe mandrel.

When the tube has been slipped over the arbor, a suitable lubricant is poured into it to facilitate bending, after which the front end of the tube is clamped to the overhanging end of the mandrel. Bending of the coil is then performed by merely running the lathe, the tube being wound automatically on the mandrel. When space is desired between the successive turns of a coil, a spacer bar is used. This bar is mounted on a sleeve which surrounds the tube being bent and the arbor rod within it. A tightly wound coil is obtained when a spacer bar is not used. When the coil has been wound to the desired length, which is usually done with reference to a stop on the mandrel, the lathe spindle is reversed to free the coil from the arbor. It can then be easily slipped off. The diameter of the mandrel must be somewhat smaller than the required inside diameter of the coil, in order to compensate for spring in the finished coil when it is released from the mandrel.

Grooved Mandrels: In bending tubing of large sizes, it is necessary to use a grooved mandrel, in addition to the support on the inside of the tube, to prevent the tube from buckling. The bending operation is practically the same as when a plain mandrel is used but the end of the inner supporting arbor has a ball type of support to guard against buckling of the tube wall. This device consists of two balls joined together with a stud. One of the balls is held in the peened-over end of a sleeve attached to the long rod over which the tube is slipped at the beginning of the operation. When the rotation of the lathe spindle is reversed at the end of an operation on a grooved mandrel, the coil of tubing is unscrewed from the grooves automatically. The tailstock center must, of course, be disconnected from the end of the mandrel.

Pipe and Tube Classifications. The following classifications are by grades and applications:

Line Pipe is furnished in sizes 1/8 inch nominal size to 24 inches actual outside diameter, inclusive, and is used principally for conveying gas, oil or water.

Pressure Piping, as distinguished from *pressure tubes,* is used for conveying fluids at normal or elevated temperatures or pressures or both, but not subjected to external heat application. The range of sizes is 1/8 inch nominal size to 24 inches actual outside diameter in differing wall thicknesses. Pressure piping is furnished in random lengths, with threaded or plain ends, as required.

Water-Main Pipe is welded or seamless steel pipe used for conveying water for municipal and industrial purposes. In application these lines are designated as flow mains, transmission mains,

force mains, water mains or distribution mains. The mains are generally laid underground. Sizes range from 1½ inch nominal size to 96 inches actual O.D. in a variety of wall thicknesses. Pipe is furnished with ends suitably prepared for mechanical couplers or for riveting, or with plain ends beveled for welding.

Structural Pipe is welded or seamless pipe made for use only as structural members, for fabrication, etc., and is not intended for conveying gases or liquids or for pressure purposes of any kind. Such pipe is furnished with plain ends only, in nominal and outside diameter pipe sizes in the commonly listed weights, and in random or definite cut lengths. It is not subjected to hydrostatic testing and is stenciled "Structural Pipe."

Large Diameter Pipe is pipe 14 inches or over intended principally for water lines, but is also used for conveying gases and liquids, or solids in suspension. Size designations refer to either actual outside diameter or actual inside diameter, and this pipe should be specified by outside diameter and wall thickness, which is preferable, or by inside diameter and wall thickness. The alternative of ordering Large Diameter Pipe by either an outside or inside diameter is an important distinction between it and Large O.D. Pipe.

Large O.D. Pipe is made in sizes from 14 inches to 30 inches actual outside diameter, inclusive. It is intended for conveying gases, liquids or other fluids and for miscellaneous uses. This pipe is specified by outside diameter and wall thickness.

Ice Machine Pipe also known as *Refrigeration Pipe* and *Ammonia Pipe* may be standard weight or extra strong butt-welded, lap-welded, electric-resistance-welded or seamless and is intended for use in the refrigeration industry. It is suitable for coiling, bending and end-to-end welding, and is air tested under water when such testing is specified by the purchaser. The sizes commonly used are 1 inch to 2 inches, furnished in random lengths unless otherwise ordered. It may be supplied with threaded ends and couplings, with threaded ends only or with plain ends, as desired.

Drive Pipe is standard weight butt-welded, lap-welded, electric-resistance-welded or seamless pipe used in gas, oil and water wells for driving into the ground or for forcing into a drilled hole to prevent caving of the walls. The ends of the pipe are specially threaded so as to permit them to butt in the coupling when made up tight. Drive pipe is furnished in 2 inches to 12 inches standard pipe sizes and 14 inches to 20 inches actual outside diameter and in random lengths, unless otherwise ordered.

Dry Kiln Pipe is butt-welded, electric-resistance-welded, or seamless pipe made for use in the lumber industry.

Signal Pipe is 1 inch standard weight butt-welded pipe intended

for use in the mechanical operation of railway signal systems. The pipe is furnished in random lengths with special signal pipe threaded ends and couplings, and generally with plugs and rivets for completing connections.

Bedstead Tubing (special light-weight pipe) is a welded product furnished with plain ends, with outside surface cleaned, or cleaned and polished for enameling purposes, and pointed-tool cut to ordered length. This tubing is not subjected to hydrostatic test.

Conduit Pipe is welded or seamless pipe intended for fabrication into *rigid conduit,* a product used for the protection of electrical wiring systems. Conduit pipe is not subjected to hydrostatic tests unless so specified. It is furnished in standard weight pipe sizes from ⅛ inch to 6 inches, in lengths approximately 10 or 20 feet, with plain ends or with threaded ends and couplings, as specified.

Conduit Tubing—EMT—is thin-wall welded tubing intended for the manufacture of that type of conduit called *electrical metallic tubing* and is made to the same inside diameters as standard weight pipe in sizes ¼ inch to 2 inches.

Casing (Oil Well) is used as a structural retainer for the walls of oil or gas wells, to exclude undesirable fluids, and to confine and conduct oil or gas from productive subsurface strata to ground level. Casing is furnished in sizes 4¾ inches to 24½ inches outside diameter, inclusive. Size designations refer to actual outside diameter and foot-weight. Ends are commonly threaded and furnished with couplings, but if desired, are prepared to accommodate other types of joints.

Tubing (Oil Well) is used within the casing of oil wells to conduct oil to ground level. It is furnished in nominal sizes 1¼ inches to 4 inches inclusive, in several foot-weights. Ends are threaded and fitted with couplings and may or may not be upset externally or internally.

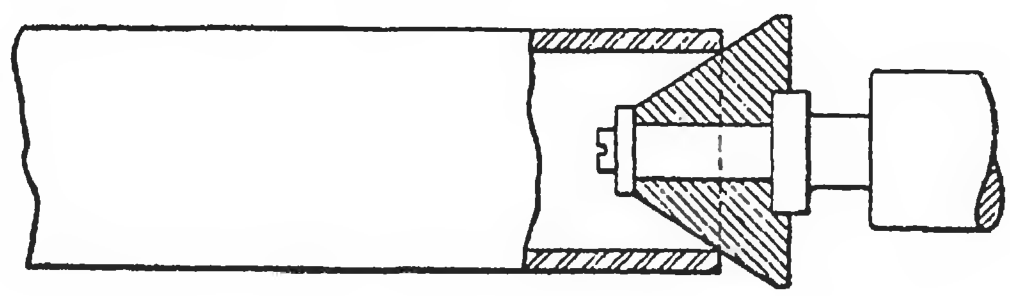
Drill Pipe (Oil Well) is used to transmit power by rotary motion from ground level to a rotary drilling tool below the surface, also to convey flushing media to the cutting face of the tool. Drill pipe is furnished in sizes 2⅜ inches to 8⅝ inches outside diameter, inclusive. Size designations refer to actual outside diameter and foot-weight. Drill pipe is generally upset either internally or externally, and is furnished with threaded ends and couplings, threaded only, or prepared to accommodate other types of joints.

Pressure Tubes, as distinguished from *pressure piping,* are used to convey fluids at elevated temperatures or pressures or both, and are suitable to be subjected to heat application. Subdivisions of this classification, embrace: boiler and superheater tubes, oil still tubes, heat-exchanger and condenser tubes.

Boiler and Superheater Tubes are used in various types of steam generating apparatus where they are subjected to pressure by water or steam at elevated temperatures either internally or externally. Size designations refer to actual outside diameter.

Oil-Still Tubes are used for carrying oil or vapors at elevated temperatures and pressures in various types of oil refining equipment in which the tube is subjected externally to furnace temperatures higher than that of the contained fluids. Still tubes are furnished in sizes up to and including 7½ inches outside diameter, and size designations refer to outside diameter, and minimum or average wall thickness. These tubes are furnished either hot-finished or cold-drawn, commonly in definite cut-lengths and with plain ends.

Heat-Exchanger and Condenser Tubes are used in various types of heat transfer apparatus in which the walls of the tube



Pipe Center for Lathe

act as a heat-transfer medium between two fluids of differing temperatures. These tubes are cold-drawn and are furnished in sizes up to 2 inches outside diameter, commonly in definite cut-lengths and with plain ends. Size designations refer to outside diameter and minimum or average wall thickness.

Mechanical Tubing is welded or seamless tubing used for a variety of mechanical purposes. It is generally made in special sizes and shapes and to special tolerances. Chemical limits and physical properties may also be specified. It may be hot-finished or cold-drawn. This type of tubing is commonly manufactured to consumers' specifications, and is used for such a variety of purposes that it is impracticable to subdivide it into classifications such as those shown for other types of tubing.

Pipe, Butt-Welded. See Butt-welded Pipe.

Pipe Center. This is a conical center (see illustration) often used for holding one end of a pipe or tube when turning the outside surface in a lathe. The conical member is free to rotate on the shank which fits into the tailstock spindle and is adjusted

with reference to the work the same as an ordinary center. A center of this type is used for holding parts having holes that would be too large for an ordinary center. The opposite end of the work is usually held in a chuck.

Pipe Center Reamer. This is a conical reamer used for reaming the ends of large holes—usually cored—so that they will fit upon a center in a lathe. The cutting part of these reamers is generally in the shape of a frustum of a cone.

Pipe Coatings and Linings. Black pipe is the term commonly applied to uncoated pipe and to pipe given an ordinary air-drying lacquer coating for protection against rust in shipment, the latter being regular mill practice. Gas, steam, air and ammonia pipe are generally furnished black.

For particular services pipe is furnished from the mill, coated or lined or both, with a variety of metallic or non-metallic materials. The metal commonly used is zinc, applied by the hot-dipped galvanizing process and widely used for protection against corrosion. Galvanized pipe is readily available from mill stocks in sizes 12 inches or smaller, also in larger sizes when specially ordered.

A large tonnage of pipe for water lines is coated or lined or both at the mill with tar base or asphalt base materials, by brushing, hot-dipping, spraying, or centrifugally spinning. Pipe for use in gas lines is commonly coated outside only. Outside coatings may be reinforced, to minimize damage to the coatings, by mechanically wrapping with heavy paper or saturated fabrics such as cotton, canvas, rag felts, or asbestos felts.

When so ordered, pipe is furnished with a primer coating designed to serve as a base for field coating.

Pipe may be internally lined with cement to meet such known corrosive actions as are withstood by cement.

When so ordered, pipe is furnished pickled to remove mill scale and dirt. It is common practice to oil after pickling.

Rubber-Lined Pipes: Rubber-insulated pipe and fittings are especially intended for the chemical industries, and are completely rubber-insulated inside and out, including flanges and bolt holes. Due to the construction, the flange couplings are flexible, and there can be no "freezing" of bolts in the rubber-lined holes. The rubber is built up in such a manner that there are no seams and laps in the entire construction.

Pipe Column. This is a strut or column made from ordinary commercial pipe. No pipe column should be used having an unsupported length greater than 120 times its radius of gyration.

Pipe Corrosion. Corrosion prevention in water piping systems involves the consideration of two major factors—the kind

of water and the kind of pipe. A few years after the introduction of brass and copper as domestic water piping material, and before troubles with these materials had an opportunity to develop, it was generally believed that they supplied the solution to the corrosion problem in buildings. Now that troubles have developed, it has become increasingly evident that no metal is immune to corrosion and that the rate of corrosion depends principally upon the characteristics of the water involved. It is not feasible to make general recommendations as to the best material to be used under all circumstances. Each individual case must be studied with particular reference to local experience and the composition of the water. The following information is from the Water Service Laboratories, New York:

Effect of Locality on Corrosion: The New York City supply is corrosive to all kinds of iron piping and yellow brass piping. The Great Lakes supply, which furnishes many municipalities along its shores, such as Toronto and Chicago, is non-corrosive because it deposits a protective mineral coating (primarily calcium carbonate) on the inside surfaces of pipes, thus insulating the pipe from the corrosive action of the dissolved gases.

Effect of Temperature: In addition to the chemical factors affecting corrosion, the physical factor, temperature, is the most important consideration controlling the rate of reaction. It is considered that a rise in temperature of about 25°F will double the speed of reaction. Thus, while a particular water may be only mildly corrosive to the cold water piping of a building, it may be very corrosive to the hot water piping. It is obvious, therefore, why specifications frequently call for less expensive pipe material in the cold water system and more expensive, more corrosion resistant, piping material in the hot water system of a building.

Pipe Materials: The various pipe materials in common use, are steel, wrought iron, the several brass alloys, and copper. The effect of corrosive waters upon iron piping, even when galvanized, is usually evidenced by the pipe lines losing their carrying capacity by becoming clogged with rust (iron oxide) caused by the direct combination of iron and oxygen. The rust formed by this oxidation reaction occupies about ten to fifteen times the volume of the iron of the pipe wall from which it was formed. Thus it is evident why iron pipe lines will become completely clogged by the rusting of only a small percentage of the pipe wall thickness. Another form of iron pipe failure is due to leaks caused by local pitting, in which case the oxygen attack is confined to small areas on the pipe wall. In addition, a common nuisance frequently arises from the fact that some of the

fine rust particles get suspended in the water, causing the familiar "red," or rusty water.

Brass Piping: The effect of corrosive waters upon brass piping takes the form of dissolving the zinc from the copper-zinc alloy. This action is known as "dezincification" and appears to be caused by the combined action of the oxygen and carbon dioxide in the water. The net result of this action is the removal of the zinc, leaving porous brittle copper which eventually causes pipe failure. Leaks usually occur first at the root diameter of the threaded joints where the metal is thinnest. Moreover, the pipe breaks easily at these points when repairs are attempted.

Yellow Brasses: Dezincification has been found to be confined to the so-called yellow brasses. There are three brass alloys commonly used. A "low" brass, or Muntz metal (60 per cent copper, 40 per cent zinc), and a "high" brass (67 per cent copper, 33 per cent zinc) are called yellow brasses. The use of these low copper content alloys has proved disappointing as compared with the previously used iron piping in many localities. In fact, many municipal authorities discourage the use of the yellow brasses and in some instances have gone so far as to actually forbid their use. The third brass alloy is referred to in the next paragraph.

Red Brass and Copper: Red brass (85 per cent copper and 15 per cent zinc) and copper are considered to be the most generally resistant to corrosion. Their increasing use, following the poor experiences with the yellow brasses, has indicated, however, that even these materials should be used with discretion. When a corrosive water acts on copper, it may dissolve a sufficient amount to produce green staining of white plumbing fixtures and laundered articles. When soap or any other alkaline material is added, the water will turn blue. The indiscriminate choice of copper pipe or tubing without regard for the composition of the local water has produced many such complaints. Many municipalities are chemically treating their water supplies in order to reduce corrosion. However, there are many limiting factors to this municipal practice, two of which are the cost of chemicals to treat the entire supply and the effect of the changed water characteristics upon existing industrial processes and power plant operation.

Pipe Coverings. Steam and feed-water pipes are protected with heat-insulating coverings in order to prevent loss of heat by radiation. Under ordinary conditions, about 3 British thermal units per square foot per hour, per degree difference in temperature, are radiated from a bare pipe. The best commercial heat-insulating materials used for pipe covering will save from 75 to 85 per cent of this loss. Among the various materials used for covering pipe may be mentioned hair felt, cork, magnesia, and

mineral wool. Asbestos is a very poor non-conductor of heat, but it may be used to advantage as a binder in other insulating substances. A common covering consists of 85 per cent carbonate of magnesia mixed with 15 per cent of asbestos. The covering should be least 1 inch thick and preferably from 2 to 3 inches, depending on the size of the pipe. It is generally manufactured in sections molded in halves to fit the pipe. Valves and fittings may be covered with the same material in a plastic state. The covering is secured in place by means of heavy duck or canvas and bands made of brass or sheet iron placed at regular intervals along the pipes. Many commercial pipe coverings are made from two or more of these substances. Pipe laid in trenches may be insulated by the use of ashes, coke, loam, or charcoal.

The actual heat losses in a steam pipe depend upon the size of the pipe, its position, the nature of the pipe surface, and the velocity of the air surrounding the pipe. Horizontal steam pipes radiate heat more rapidly than vertical pipes, the reason for this being that the heated air surrounding a vertical pipe travels upward along the surface of the pipe, while with horizontal pipes the heated air rises immediately upon being heated, thus making room for cooler air, which is, in turn, heated. For all practical purposes, however, it is customary to assume a loss of 3 B.T.U. per square foot, per hour, for each degree F. difference in temperature between the steam in a bare steam pipe and the air surrounding the pipe. Tests made on an 8-inch standard steam pipe 60 feet long, carrying steam at from 109 to 117 pounds per square inch gage pressure, and surrounded by air at temperatures varying from 58 to 81 degrees F., showed that each square foot of bare pipe surface radiates approximately 2.706 B.T.U. per hour, per degree average difference of temperature between the steam in the pipe and the outside air.

Pipe Discharging Capacity. There are many formulas for calculating the discharge of water through a pipe; some of them are quite complicated, and all are, and must of necessity be, approximate. It is impossible to derive one formula that will fit every case. The pipe, or conduit, is made of various materials, and the friction of the moving water varies greatly with the material of which the pipe is composed. Even for a particular material, the discharge will not be the same for a pipe that has been in use a long while as for a new pipe. The impurities carried by the water stick to the pipe, causing it to become foul; this reduces the diameter and discharge, and also alters the resistance due to friction. If the slope is not gradual and even, air will accumulate at different points; this also reduces the discharge, since the area of the cross-section at those points is less. Bends, especially those of short radius, reduce the velocity and, consequently,

the discharge. Contractions and enlargements, likewise, exert a deterrent effect.

As a result of the examination and comparison of a large number of experiments, the following formula has been derived; it is simple in form, is said to give good results, and is adapted to logarithmic computation: $v = 0.0757cd^{2/3}\left(\frac{h}{l}\right)^{\frac{1}{2}}$, in which v = velocity, in feet per second; d = diameter of pipe, in inches; h = head, in feet; l = length of pipe, in feet; and c = a constant the value of which depends on the material of which the pipe is composed. For new, smooth, wrought-iron pipe, laid straight and without bends, c may be taken as 160. Since the actual internal diameter of a 1½-inch pipe is 1.61 inches, the velocity of discharge in the pipe is $v = 0.0757 \times 160 \times 1.61^{2/3} \times \left(\frac{60}{2640}\right)^{\frac{1}{2}}$ = 2.508 feet per second. The number of cubic feet per minute discharged is $\frac{60 \times 2.508 \times 0.7854 \times 1.61^2}{144} = 2.127$; $2.127 \times 7.48 = 16$ gallons per minute.

Pipe Fittings. There are several American Standards for pipe fittings to meet the wide range of requirements both as to size of fitting and allowable working pressure. The different standards and classes of fittings are based primarily upon allowable pressures and whether the fitting is of the flange-and-bolt type or the threaded-joint type.

Cast-Iron Flanged Fittings—25 Pounds Pressure: These fittings are for a maximum working saturated steam pressure of 25 pounds per square inch. (All pressures are gage pressures.) Fittings such as elbows, tees, side outlets and straight crosses are for nominal pipe sizes ranging from 4 to 72 inches. The 36-inch and smaller sizes may be used for maximum non-shock hydraulic pressures of 43 pounds per square inch, or maximum gas pressure of 25 pounds per square inch at or near the ordinary range of air temperatures.

Cast-Iron Flanged Fittings—Class 125: These fittings, in sizes from 1 inch to 5 inches, inclusive, are for maximum saturated steam service pressures of 125 pounds per square inch. The pressure ratings for larger sizes have been revised downward to conform to modern practice and keep the safety factors on a more conservative basis. These revisions follow: Sizes 6 to 12 inches, inclusive, 100 pounds per square inch; sizes 14 to 24 inches, inclusive, 80 pounds per square inch; sizes 30 to 48 inches, inclusive, 50 pounds per square inch. For maximum water service pressures at or near the ordinary range of air temperatures, the

pressure ratings are 175 pounds per square inch for 1- to 12-inch sizes, inclusive. The rating for flanges only is 150 pounds per square inch for 14 to 48 inches. The regular elbows, tees, side outlets and crosses are for nominal pipe sizes ranging from 1 to 48 inches.

Cast-Iron Flanged Fittings—250 Pounds Pressure: This standard applies to maximum working saturated steam pressures of 250 pounds per square inch. Fittings of 10-inch size and smaller may also be used for maximum non-shock working hydraulic pressures of 325 pounds per square inch at a temperature of 250 degrees F. and maximum non-shock working hydraulic pressures of 400 pounds per square inch at or near the ordinary range of air temperatures. The elbows, tees, side outlets and straight crosses are for nominal pipe sizes ranging from 1 to 30 inches.

Cast-Iron Flanged Fittings—800 Pounds Pressure: These fittings are for maximum non-shock working hydraulic pressures of 800 pounds per square inch at or near the ordinary range of air temperatures. This standard covers nominal pipe sizes ranging from 2 to 12 inches.

Steel Flanged Fittings: The pressure ratings range from 150 to 2500 pounds per square inch. The 150- and 300-pound classes cover nominal pipe sizes from 1 to 24 inches. The 400-, 600-, 900- and 1500-pound classes cover nominal pipe sizes from ½ to 24 inches. The 2500-pound fittings are for pipe sizes ranging from ½ to 12 inches. The materials for these fittings may be either steel castings or steel forgings.

Malleable-Iron Screwed Fittings—150 Pounds Pressure: This pressure rating of 150 pounds per square inch is a recommended maximum for saturated steam service pressure. The maximum hydraulic service pressure rating, including shock, is 300 pounds per square inch at or near the ordinary range of air temperatures. The elbows, tees and crosses in the regular straight sizes are for nominal pipe sizes ranging from ⅛ to 6 inches, inclusive. The threads conform to the American Standard taper pipe thread.

Cast-Iron Screwed Fittings—125 Pounds Pressure: The maximum working saturated steam pressure is 125 pounds per square inch. The elbows, tees and crosses in regular straight sizes are for nominal pipe sizes ranging from ¼ to 16 inches.

Cast-Iron Screwed Fittings—250 Pounds Pressure: The maximum working saturated steam pressure is 250 pounds per square inch. The elbows, tees and crosses in regular straight sizes are for nominal pipe sizes from ¼ to 16 inches.

Pipe Flange Faces. Pipe flanges which have the entire face of the flange faced straight across, and use either a full face or ring gasket, are commonly employed for pressures less than 125 pounds on steam and water lines. The best results are ob-

tained by using a fairly thick gasket, so that the gasket will have sufficient pressure exerted on it by the bolts to make a tight joint before the outside edges of the flanges meet. The full-faced gasket is preferred by some, because it may be installed more readily and is more likely to be concentric with the bore of the flange than that of a ring gasket, but it has no other advantages. A ring gasket, properly proportioned and correctly applied, will make just as tight a joint as a full-faced gasket, at considerable less expense and with less pulling up on the bolts.

Raised Face, Smoothly Finished for Gaskets: This type of face is made by raising the face of the flange between the bore and inside of the bolt holes from 1/32 to 1/16 inch above that of the remainder of the flange. This type of joint is most satisfactory on high-pressure steam lines, and is the most generally used. With this style of face, ring gaskets are employed, and a greater pressure per square inch of gasket is obtained by pulling up on the bolts than would be obtained with similar bolts on a full-faced gasket. The raised face prevents the touching of the outside edges of the flanges, and the entire pressure exerted by the bolts is transmitted to the gasket, which gives a maximum efficiency and resistance against leakage.

Raised Face, Ground Joints: This style of face is identical with that employed when gaskets are used, excepting that the raised face is ground to an absolute metallic joint. This eliminates the use of gaskets. This style of joint was popular before a satisfactory gasket material was found, and was employed considerably on superheated steam lines. There are now on the market gaskets which are employed for temperatures as high as 800 degrees F.; the successful use of these gaskets has to a considerable degree reduced the number of ground joints used in steam lines. See also Corrugated Flanges.

Pipe for Acids. Pipes for carrying acid liquids, when made from steel, will usually last for a short time only. Wrought-iron pipes will last somewhat longer, but are not satisfactory. A steel to which 0.5 per cent of copper has been added has given good results for pipes of this kind. Valves made from ferro-silicon will resist the corrosive action of acid liquids to a considerable extent. Their first cost is higher, but their resistance to the action of the acid warrants their use.

Pipe Joint Cements. See Cements for Joints.

Pipe, Lead. See Lead Pipe.

Pipe of Riveted Type. Very large sizes of pipe are frequently made from boiler sheet steel and provided with riveted joints, the seams being longitudinal or helical. This class of piping is frequently used in large hydraulic installations where

the ordinary pipe sizes would be of insufficient capacity for the volume of water passing through them. The helical-seam riveted pipe was invented by John B. Root, and by him termed "spiral riveted pipe." The helical seam makes it possible to obtain in a riveted pipe practically the full strength of the plate; with a longitudinal riveted seam, from 60 to 65 per cent of the strength of the plate is all that can be expected of the riveted seam.

Pipe Reamers. Pipe reamers are used for reaming taper holes previous to tapping by standard taper pipe taps. They are made in sizes corresponding to those of pipe taps, and the taper is the same—¾ inch per foot. They are fluted with the same kind of cutters as are used for straight reamers of sizes corresponding to the diameter at the small end of the pipe reamers.

Pipe Schedule Numbers. The American Standard for Wrought Iron and Wrought Steel Pipe includes a series of wall thicknesses which are designated by schedule numbers. Welded and seamless steel pipe, according to this standard, has two wall thicknesses for each nominal pipe size from ⅛ to ⅜ inch, inclusive; three wall thicknesses for each nominal pipe size from ½ to 3 inches, inclusive; four wall thicknesses for each size from 4 to 6 inches, inclusive; nine wall thicknesses for each size from 8 to 12 inches, inclusive; and ten wall thicknesses for each O.D. pipe in nominal sizes from 14 to 24 inches, inclusive. Welded wrought iron pipe has two wall thicknesses in each size from ⅛ inch to 6 inches, inclusive, and from three to six wall thicknesses for each of the larger sizes. The ten schedule numbers for welded and seamless steel pipe are 10, 20, 30, 40, 60, 80, 100, 120, 140, and 160. These schedule numbers indicate approximate values of the expression $1000 \times P/S$, in which $P =$ internal pressure in pounds per square inch and $S =$ allowable fibre stress in pounds per square inch. This permits an approximation of the wall thickness if the service pressure and the value of allowable stress for the material and service conditions are known. Recommended values of S, the allowable stress, may be obtained by reference to engineering codes such as the A.S.M.E. Boiler Code, the American Standard Code for Pressure Piping (ASA B31.1), etc.

It is contemplated that the user will compute the exact value of wall thickness suitable for the conditions for which the pipe is required, as described in detail in the A.S.M.E. Boiler Code, the American Tentative Standard Code for Pressure Piping (ASA B31.1). From the schedules of nominal thicknesses, a thickness may then be selected to suit the value computed to fulfill the conditions for which the pipe is desired. The thicknesses represented by schedules 30 and 40 are identical with thicknesses for "standard weight" pipe in former lists, whereas thicknesses

equivalent to schedules 60 and 80 are identical with thicknesses for "extra strong" pipe. The thicknesses represent the nominal or average dimensions and include an allowance for mill tolerance of 12½ per cent under the nominal thickness.

Pipe Size Designation. Nominal sizes of steel and wrought iron pipe represent the approximate inside diameter for sizes up to 12 inches, inclusive. The larger nominal sizes represent the outside diameter. Changes in thickness and weight of the various grades are made by varying the inside diameter only. The outside diameter remains constant so that any grade of pipe may be used with any grade of fitting, flange, coupling, or valve. When the nominal size indicates the approximate inside diameter, it may differ considerably from the true inside diameter, especially when the pipe has exceptionally thick walls. For example, the inside diameter of pipe having a nominal size of 2 inches may vary from 2.067 to 1.939 as the wall thickness is increased from 0.154 (schedule 40 of the American Standard) to 0.218 (schedule 80). Another method of specifying pipe sizes, which has been used to a limited extent, is to give the outside diameter and the wall thickness. To illustrate, a pipe may be designated as 4 O.D. with 0.226 wall or this may be simplified to 4 by 0.226 inch pipe. This designation would represent the present nominal size of 3½ inches with a schedule 40 wall thickness which is equivalent to the weight previously designated as standard.

"Pipes" in Steel Ingots. In the preparation of steel for rolling into bars and various structural shapes, the first step is to pour the molten steel into molds, thus forming ingots. As the steel gradually solidifies, a more or less cone-shaped cavity forms at the top of the ingot. This is known as the *pipe.* Piping is caused by the side of the ingot cooling faster than the central part. As the metal in the ingot cools and solidifies toward the sides, the still molten metal at the center separates and a "pipe" forms. There is a greater tendency for a pipe to form at the top of the ingot than farther down, because formation in the lower part is offset by the metal from the upper part of the ingot filling the space formed.

After the metal solidifies, further cooling and contraction tends to open the pipe farther toward the bottom because the colder exterior is more rigid and is capable of stretching the more elastic interior. The surface of this pipe or cavity is likely to become more or less oxidized. Since this oxidized portion is not welded or amalgamated in rolling, the pipe will appear in the smallest rod or wire into which this part of the ingot may be rolled. The only way to avoid the defects due to this pipe is by discarding that part of the ingot containing it. Various methods of reducing the pipe and resulting waste have been tried. One

plan is to squeeze the partially solidified ingot so as to close up the pipe. This, however, requires the use of very heavy hydraulic equipment and is expensive. The pipe may be shortened by casting with the large end of the mold up. This method may also be combined with the use of a "hot top" mold. This is the method generally employed. The larger end is surmounted with a short mold lined with a refractory and non-conducting material such as clay. This lining reduces the size of the top section and keeps the top in the molten state until the ingot proper has solidified. The pipe is thus brought up in the cope or sink head which is of much smaller section than the ingot, thus decreasing the waste accordingly.

Pipes, Steam-Flow Capacity. See Darcy's Formula.

Pipe Taps. A taper pipe tap is a hand tap used for tapping all kinds of American Standard taper pipe fittings, either by machine or by hand.

Straight Pipe Taps: A hand tap exactly the same in every way as the taper pipe tap except that the threaded portion is straight and of proper size for tapping American Standard straight pipe threads.

Combined Pipe Tap and Drills: A taper pipe tap having an extended point suitable for drilling and a taper square shank. Used for drilling and tapping holes in range boilers and similar work in one operation.

Pipe, Test for Wrought-Iron and Steel. Wrought-iron pipe may be distinguished from steel pipe by testing the material in the pipe for manganese, which is present in the steel pipe, but is not present, except possibly as a trace, in wrought iron. A method of making the manganese test is as follows: Place a clean, bright chip or filing of the metal to be tested, about the size of a pinhead, in a porcelain crucible; add six drops of pure nitric acid, and heat; add two drops of silver nitrate solution, then one crystal of ammonium persulphate not greater than 1/8 inch in diameter; warm the solution, but do not let it boil. If the metal is steel, a pink color will begin to develop, and at this point the crucible should be removed from the source of heat, when a very decided red coloration will result. If no color develops, but a small amount of dark residue remains in the dish the metal is wrought iron.

Pipe Thickness Formula. In developing the American Standard (B36.10 — 1939) for wrought-iron and wrought-steel pipe, a survey of current practice in the piping industry was employed by the Committee as the logical starting point. Before making this survey, however, the Committee developed a basic formula for its own guidance in setting up theoretical wall thicknesses

for a wide range of pressure-stress ratios. *This formula is not to be used for design.* It was developed solely for the purpose of determining a rational set of pipe thicknesses reasonably consistent with the usual "basis-of-design" formulas, and is given here as a matter of record only:

$$t = \left(\frac{P}{S} \times \frac{D}{1.75}\right) + 0.1$$

In this formula, P = internal pressure, lb. per sq. in.; S = allowable fiber stress, lb. per sq. in.; D = outside diameter of pipe, in.; t = nominal wall thickness, in.

This formula is a modification of the Barlow formula for pipe wall thickness, with a constant addition of 0.1 inch in thickness to compensate for threading and corrosion. This plan is similar to the one recommended in the A.S.M.E. Boiler Code, but in addition it includes an allowance for under-thickness mill variation of 12.5 per cent. Analysis by this formula showed that up to 12 inches in size, common usage had largely centered on four schedules of wall thicknesses corresponding approximately to definite pressure-stress ratios which could be expressed simply as 1000 $\times$ P/S equaling 40, 80, 120, and 160. These schedules were projected for pipes larger than 12 inches and up to 30 inches. Wall thicknesses from current practice were then selected for the intermediate series equaling 60, 100, and 140. From the light wall O.D. sizes and from certain 8-, 10-, and 12-inch standard pipes used in large quantities, three additional schedules were set up for low pressures.

The formula was not applied to sizes smaller than 1 inch. However, dimensions and weights which have been traditional in commercial lists for "standard weight" and "extra strong" schedules have been retained in pipe sizes ⅛ inch to ¾ inch, inclusive. The terms "standard," "extra strong," and "double extra strong" in the old terminology, however, have been discarded in the American Standard. See also Pipe Schedule Numbers.

Pipe Thread. The American Standard pipe thread (formerly known as National Standard and as the American Briggs Standard) has an angle of 60 degrees, and the crest and root are truncated an amount equal to 0.033 $\times$ pitch of thread except for 8 threads per inch which (according to 1942 revision) are truncated 0.045 $\times$ pitch at the crest and 0.033 $\times$ pitch at the root. The (basic) maximum depth of the truncated thread is 0.80 $\times$ pitch except for 8 threads per inch which is 0.788 $\times$ pitch. The taper of the thread is 1 in 16 or 0.75 inch per foot, measured on the diameter and along the axis. The pitch diameter at the end of the pipe thread and at the gaging notch of the plug gage, as

well as the effective pipe thread length, are determined by the following formulas:

$$F = B - (0.05\ B + 1.1)\ P;\ E = F + 0.0625 \times D;$$
$$C = (0.8 \times B + 6.8)\ P$$

in which F = pitch diameter at end; E = pitch diameter at gaging notch; B = outside diameter of pipe; D = normal engagement, by hand, between external and internal threads; C = effective length of external thread; P = pitch of thread. The American Briggs Standard tapered pipe thread is cut so that the thread is at right angles to the pipe axis; this now is also the accepted practice for British tapered pipe threads, although formerly it was the usual British practice to cut the thread at right angles to the surface of the cone.

Straight Pipe Thread: The straight pipe thread is the same as American Standard taper pipe thread in regard to pitch and depth of thread. The basic pitch diameter for straight pipe threads equals the pitch diameter at the gaging notch of the taper plug gage. The straight pipe thread is gaged with a taper threaded plug gage and should gage flush at the face with the gaging notch, allowing a maximum variation of one turn plus or minus from the notch.

Pipe Thread, British Standard. The form of thread is that of the Whitworth system; the sides of the thread form an angle of 55 degrees with each other, and the top and bottom of the threads are rounded to a radius equal to 0.1373 × the pitch of the thread. For taper pipe threads the taper is ¾ inch per foot, or 1/16 inch per inch, measured on the diameter. This system has been approved by the British Standards Institution as the standard pipe thread system in Great Britain. This standard is applied to iron and steel pipes and tubes for water, steam and gas.

Pipe Threading Machines. There are two general types of pipe threading and cutting-off machines. The most common type is so arranged that the pipe is revolved while the thread is cut by stationary dies; with the other type, the pipe is held stationary while the die-head is revolved. The die-head contains several equally-spaced chasers, the number depending upon the pipe sizes for which the machine is intended. The die-head is so arranged that these chasers can be moved after a thread has been cut, thus permitting them to be withdrawn from the threaded end. A common method of securing this outward movement is by means of a cam ring which is turned slightly by a hand lever. The die-head is so constructed that the chasers are locked when in the cutting position, and provision is made for adjusting them in order to cut threads which are either larger or smaller than the standard size.

The chasers should preferably be so located or ground that the front of each chaser will have a certain amount of rake, in order to insure cutting a clean thread, and also to reduce the amount of power required for the threading operation. The *cutting-off attachment* is a feature common to pipe threading machines in general. This attachment is located directly back of the die-head, and is used for cutting off pipes preparatory to threading. Some pipe threading machines have a *reaming attachment* for removing the burr which is formed on the inside of the pipe by the cutting-off tool.

Pipe Working Pressures. Standard weight pipe is commonly used for heating work, exhaust lines, and all pressures below 100 pounds per square inch; extra heavy pipe should be employed for pressures from 100 to 200 pounds per square inch, and where there is liable to be considerable corrosion. The pressures are far below the ultimate strength of the pipe. Special hydraulic pipe for service on lines requiring the highest possible grade of material and workmanship are bored from solid forgings and are made to order for pressures up to 10,000 pounds per square inch. If seamless steel tubes are assumed to have a strength of 100 per cent, butt-welded steel pipe has a comparative strength of 73 per cent, and lap-welded steel pipe of 92 per cent. From this it will be seen that the strength of a butt-weld is only about 80 per cent of that of a lap-weld. The relative strengths of wrought iron and steel pipe are as follows: Butt-welded wrought-iron pipe has 70 per cent of the strength of similar butt-welded steel pipe, and lap-welded wrought-iron pipe has 57 per cent of the strength of similar lap-welded steel pipe.

Piston Alloys, Aluminum. The S A E Standard No. 321, Type 2 alloy, has a low coefficient of expansion and other desirable mechanical properties at elevated temperatures and is adapted for automobile engine pistons. For composition, see S A E Standard No. 321 under Aluminum Alloys, Cast.

Piston Displacement. Piston displacement is the volume which is swept through by a piston working in a cylinder. This volume is equal to the area of the piston multiplied by the length of its travel. See also Pump Displacement.

Piston Packing Rings. The pistons of steam engines, gas and gasoline motors, as well as other pistons which are required to move freely in a cylinder, must be slightly less in diameter than the diameter of the cylinders in which they operate.

Piston Allowances: In steam engine work, the allowance usually varies from 0.015 to 0.020 inch for each foot of cylinder diameter. Applying this rule to a 24-inch locomotive cylinder,

the clearance would be about 1/32 inch. A gas or gasoline engine piston should fit into the cylinder so as to allow for the necessary oil film and to provide for slight distortions in shape under heat, but still close enough to prevent excessive leakage and loss of compression. The question of the ideal allowance to make is considered apart from that of manufacturing tolerances. Some engineers use the very convenient rule of making the piston 0.001 inch small for each inch diameter of the cylinder bore, but the following rule comes closer to actual requirements: Allow from 0.002 to 0.0025 inch as a maximum for each inch of cylinder diameter above two inches. As it is commercially impossible to manufacture parts that are all exactly alike, due allowance must be made for variations.

Types of Piston Packing Rings: In order to secure a tight joint between a piston and the cylinder in which it operates, piston or packing rings are used, the function of the rings being to seal the clearance space between the piston and cylinder and form as nearly as possible a tight joint. These rings vary greatly in design, many attempts having been made to construct a ring that would give a perfectly tight joint. The two types of ring shown in Fig. 1 have been widely used in steam engines or wherever such a simple type of ring will serve the purpose. While such rings do not form a joint that is absolutely tight, they are comparatively inexpensive to produce. In gasoline motors, improved forms of special patented rings are used.

Concentric and Eccentric Rings: The concentric ring *A* is of uniform thickness, whereas the eccentric ring, Fig. 1, varies in thickness, as the illustration shows, the bore of the ring being somewhat off center. The reason for making a ring eccentric is to obtain a uniform pressure against the cylinder wall all around the circumference. In the ideal or theoretical eccentric ring, the reduction of thickness in proportion to the gradually decreasing stiffness of the ring, from the point of maximum thickness to the thinnest part, will serve to give a uniform radial pressure. In actual practice, however, the rings are not made to conform to the exact theoretical shape, and the uniform pressure is not obtained, although eccentric rings are superior in this respect to an ordinary concentric ring which has not been made by a special method.

One objection commonly referred to in connection with eccentric rings is that, owing to the eccentricity, there is considerable space beneath the ring on the thin side, since the depth of the ring groove in the piston is uniform. This space makes it easier for gas or steam to blow through. Trouble of this kind naturally depends, to some extent, upon how carefully the rings are made and fitted.

Ring Diameter Before Splitting: Piston rings of the general type illustrated in Fig. 1 are inserted in grooves in the piston, and are compressed sufficiently, when assembled in the cylinder, to bear tightly against the cylinder wall. The increase in ring diameter over the cylinder diameter, to obtain the required expansion varies more or less for different types of rings and ring castings. One rule is to make the ring diameter before splitting equal to the cylinder diameter multiplied by 1.02 to 1.027.

Ring Thickness: In order to insert an ordinary eccentric or concentric piston ring in the groove of a one-piece piston, the ring must be sprung open enough to permit it to pass over the piston. The strains to which a ring is subjected when it is being expanded over the piston, and also when it is compressed into the

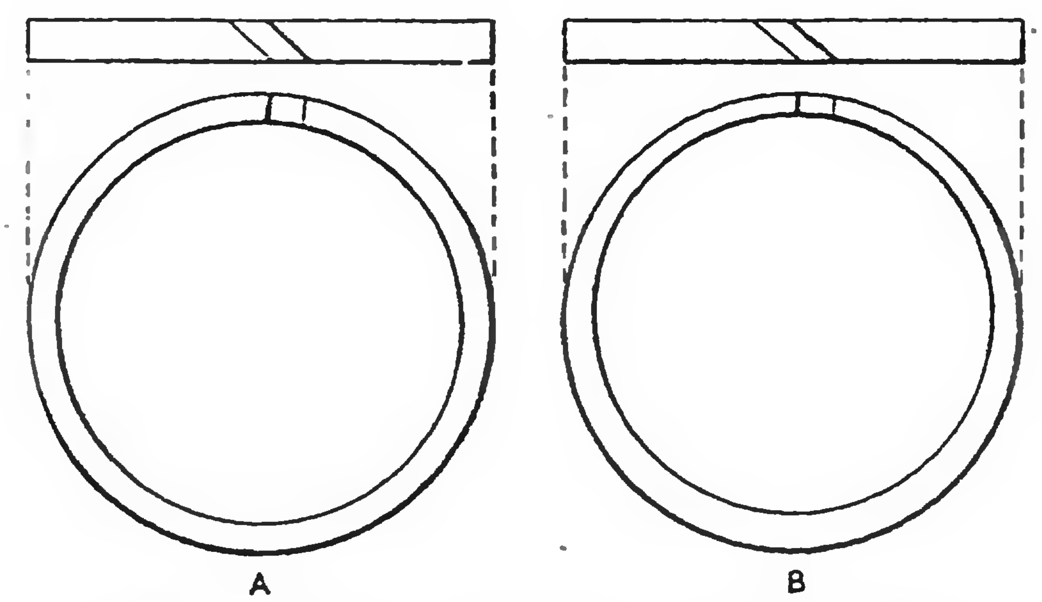


Fig. 1. Concentric and Eccentric Piston Packing Rings

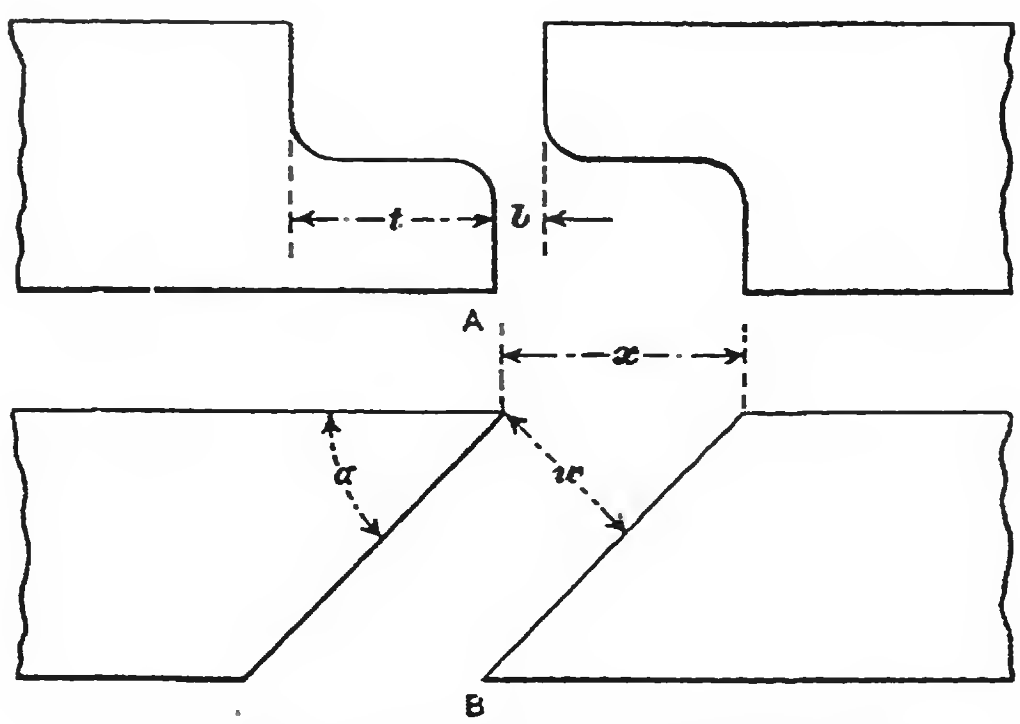


Fig. 2. (A) Lap Joint. (B) Diagonal Joint

cylinder, depend upon the thickness of the ring in proportion to the diameter. Therefore, rings are so proportioned that the material will not be over-stressed, either when inserting the ring over the piston or when it is compressed to the cylinder size. It is considered good practice to so design a ring that it will be subjected to about the same stress when being expanded over the piston as when it is compressed in the cylinder, because, under these conditions, a ring exerting a certain pressure per square inch against the cylinder will be subjected to the least total strain, and the chance of breakage will be reduced to a minimum. When expanding a ring over the piston, and also when compressing it, the stress will be greatest at a point opposite the joint; hence, the thickness at this point should be considered in the case of an eccentric ring.

For a concentric ring, a thickness equal to approximately 1/32 of the cylinder diameter is, according to one rule, about the maximum thickness that the ring can have and still be inserted over the piston without breakage. An eccentric ring may be made somewhat thicker than cylinder diameter ÷ 32, because of the gradual reduction in the thickness toward the joint. A ring having a thickness equal to cylinder diameter ÷ 27.5 should, if made of a good cast iron, be thick enough to give the necessary pressure against the cylinder wall and yet not be so thick as to result in over-straining the ring when the latter is expanded over the piston.

Ring Width: The proportions of piston rings of the types shown in Fig. 1 vary more or less among different engine manufacturers. The concentric ring *A* usually has a width that slightly exceeds the thickness, although rings of square section are often used and, in some cases, the thickness exceeds the width. When rings are properly made, so that they have an even bearing all around the circumference, nothing is gained by making the width greater than 1½ × maximum thickness. It is considered good practice to make the width equal to the cylinder diameter × 0.05.

Amount to Cut Out of Ring: The amount to cut out of the ring to permit contracting it to the cylinder diameter (or to this diameter plus a grinding allowance) equals the circumference of the ring before splitting minus the circumference when the ring is compressed, plus a small clearance to allow for expansion when the ring is in the engine cylinder and its temperature rises. When the ring is compressed to the cylinder diameter plus the amount allowed for grinding, the ends should be a distance apart equal to the cylinder diameter × 0.004 to allow for expansion. It will be assumed that the ring, before being compressed, has a diameter equal to 1.027 × the cylinder diameter, and that the grinding allowance for truing the outer surface after compression, is 0.008

$\times$ the cylinder diameter; then the outside diameter of the turned ring would equal 1.035 $\times$ cylinder diameter, and the outside diameter of an unground ring compressed to the cylinder diameter, plus the grinding allowance, would equal 1.008 $\times$ cylinder diameter. In order to cut enough out of the ring to obtain this latter dimension, the reduction along the outer circumference of the ring should equal 0.085 $\times$ cylinder diameter. Therefore, the total amount to cut out of the ring equals 0.085 $\times$ cylinder diameter $+$ a clearance allowance between the ends equal to 0.004 $\times$ cylinder diameter. A result accurate enough for practical purposes will be obtained by the following rule:

The amount to cut out of the piston ring as measured along the outer circumference $=$ cylinder diameter $\times$ 0.09.

Width of Cutter for Diagonal Joint: The amount to cut out of a ring, as determined by the foregoing rule, applies to either a concentric or eccentric ring, since it is the amount in a circumferential direction. In the case of a diagonal joint, however, the width of the cutter will be less than this amount. In the diagram *B,* Fig. 2, the length x represents the cylinder diameter $\times$ 0.09, and w, the required width of the cutter. To obtain this cutter width w, multiply the dimension x by the sine of the joint angle a. The angle a between the diagonal joint and the side of the ring varies between 30 and 45 degrees, and is usually 30 degrees. For 30 degrees $w = x \times 0.5$; for 45 degrees, $w = x \times 0.707$.

Grinding the Outside of Rings: It is very important to make piston rings so that they are truly cylindrical after being compressed to the size of the cylinder bore. In order to make accurate rings, it is necessary to turn or grind them to the required diameter while compressed the same as they will be when in the cylinder. The split rings to be ground are compressed and inserted in a locating sleeve or cylinder; they are then clamped in place between a shoulder and nut or between clamping flanges. Then the locating sleeve is removed. The inside diameter of this sleeve should be equal to the cylinder diameter plus the amount left on the rings for grinding.

Piston-Ring Peening. See Peening Piston-rings.

Pitch and Lead of Screw Thread. The terms "pitch" and "lead" of screw threads are often confused. The pitch of a screw thread is the distance from the center of one thread to the center of the next thread, whether the screw has a single, double, triple, or quadruple thread. The *lead* of a screw thread is equal to the distance a nut will move forward on the screw, if it is turned around one full revolution. The pitch and lead of a single-threaded screw are equal. With a double-threaded screw the nut will move forward in one revolution, an amount equal to twice

the pitch, so that the lead of a double-threaded screw equals twice the pitch. The lead of a triple-threaded screw equals three times the pitch, and the lead of any other multiple screw can be determined by multiplying the number of threads by the pitch. The lead may also be expressed as the distance from center to center of the *same* thread, after one turn.

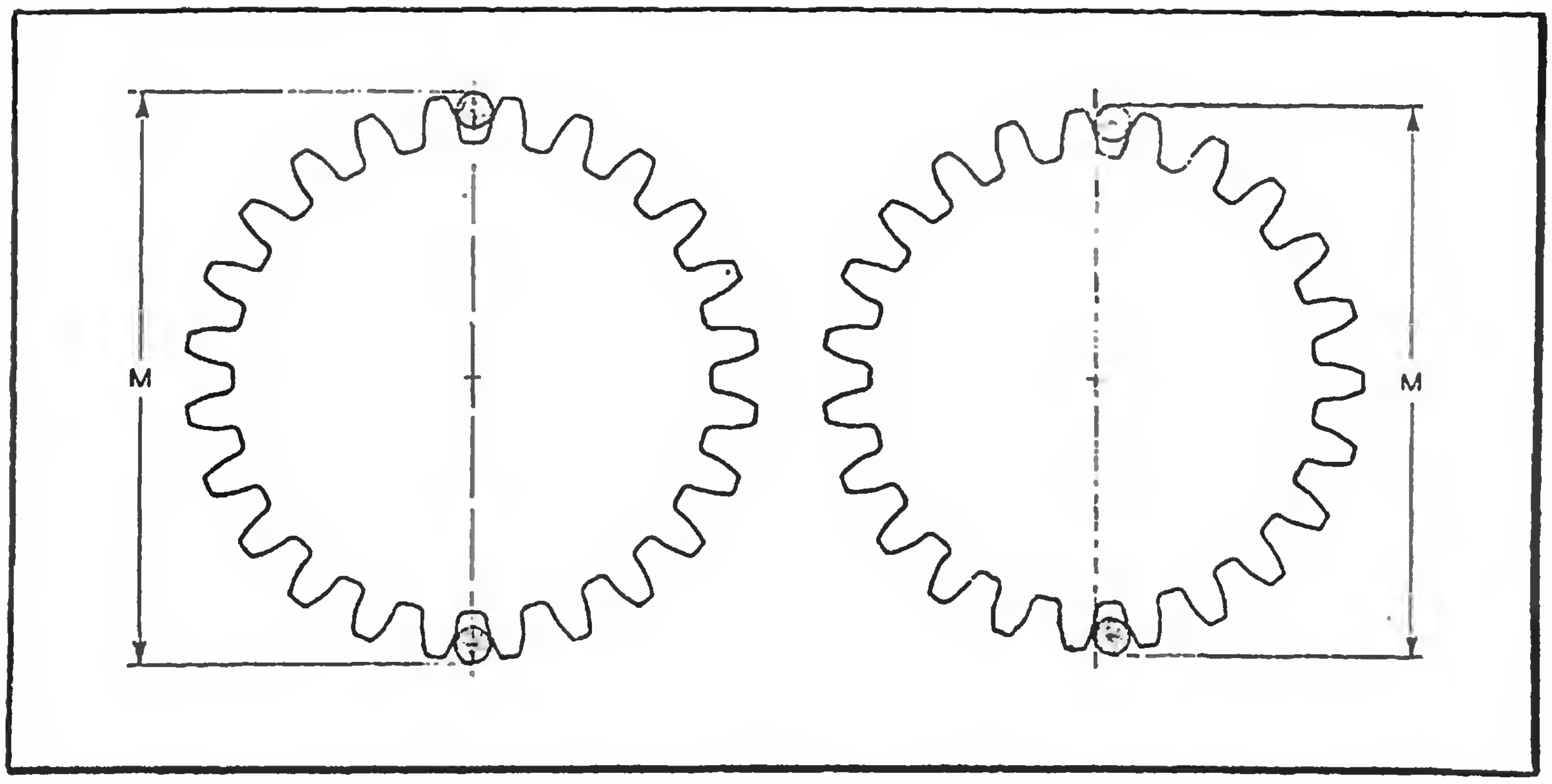
Pitch Circle. The pitch circles of two spur gears in mesh always intersect the common center line at the point where the line of action crosses this center line. Ordinarily a pair of involute gears is designed for a given center-to-center distance, but these gears might be separated somewhat and it would still be possible for one to transmit motion to the other at a uniform rate, although this would cause a certain amount of backlash or play between the intermeshing teeth. However, if two gears were assembled so that the center distance was somewhat greater than standard (as is sometimes done to meet a special condition) the pitch circles would be enlarged and the pressure angle increased, but the base circles would remain the same, the involute curvature of the teeth not being changed. The reason why the pitch circles would become larger will be apparent when it is remembered that the radius of each pitch circle is equal to the distance from the gear center to the *pitch point* or the point where the line of action intersects the common center line. See also Pitch Diameter.

Pitch Cone. The pitch cone of a bevel gear is equivalent to a cone which, if mounted on the shaft in place of the bevel gear, would drive or be driven by the frictional contact with the pitch cone of its mating gear in the same velocity ratio (if no slip occurred) as that of bevel gears having correctly formed teeth.

Pitch Cone Angle. The pitch cone angle of a bevel gear is the angle which the pitch line makes with the axis of the gear. This is sometimes referred to merely as "pitch angle."

Pitch Cone Radius. The pitch cone radius of a bevel gear is the distance measured on the pitch line from the vertex of the pitch cone to the outer edge of the teeth. This dimension is also known as the "cone distance."

Pitch Diameter of Gear. The pitch diameter, as ordinarily applied in the design of spur and bevel gears, equals the number of teeth divided by the diametral pitch. The actual pitch circle, however, when, say, two spur gears are in mesh, is established by the intersection of the line of action and the common center line. The pitch diameter of a bevel gear is the distance across the gear at the point where the pitch lines intersect the outer edges of the teeth; in other words, the pitch diameter is measured at the large ends of the teeth.



Method of Checking Pitch Diameter of Spur Gear by Measurement over Pins

Checking Pitch Diameter by Pin Method: When spur-gear sizes are checked by the pin or roll method, cylindrical pins of known diameter are placed in diametrically opposite tooth spaces; or, if the gear has an odd number of teeth, the pins are located as nearly opposite as possible. (See illustration). The measurement *M* over these pins is then checked by using any sufficiently accurate method of measurement. The general formulas for determining what the measurement over the pins should be, when the gear pitch diameter is correct, are not included here because they are cumbersome to apply and involve the use of a table of involute functions. (Measurement *M* over pins may be obtained simply by dividing tabulated constant in MACHINERY'S HANDBOOK by diametral pitch of gear.) This method of checking gear sizes by measurement over pins is especially useful in shops having a limited gear-inspection equipment.

Pitch Diameter of Screw. On a straight screw thread, the "pitch diameter" is equivalent to the diameter of an imaginary cylinder which would pass through the threads at such points as to make the width of the threads and the width of the spaces cut by the surface of the cylinder equal. Thus the pitch diameter is equal to the outside or major diameter minus one thread depth. (See diagram accompanying Screw Thread Definitions.)

The pitch diameter is important because contact between any threaded plug, bolt, etc., and a threaded hole, should be on the sloping sides of the thread and not at the crest or root. This is the reason why some method of checking the diameter that is related to these angular sides is desirable. The pitch diameter serves this purpose because it is across the angular sides of the

thread. This will be more apparent when the method of measuring the pitch diameter is understood. Pitch diameter is also known as the "effective diameter" and sometimes as the "angle diameter." The pitch diameter may be checked very accurately by what is known as the "three-wire method." See Thread Measurement, Three-wire Method.

Pitch of Gear. Pitch, as used with reference to gear teeth, defines the sizes of the teeth. Two kinds of pitches are used, *circular pitch* and *diametral pitch.* The circular pitch is the distance along the pitch circle from the center of one tooth to the center of the next. The pitch circle at the larger or outer ends of the teeth is used for determining the circular pitch of a bevel gear. The diametral pitch is the ratio or quotient obtained by dividing the number of teeth by the pitch diameter.

Pitch of Rivets. The pitch of rivets is the distance from the center to center of adjacent rivets. The pitch should be as large as possible without impairing the tightness of the joint when under pressure. For single-riveted lap-joints in the circular seams of boilers which have double-riveted longitudinal lap-joints: Pitch $= d \times 2.25 = t \times 5$, approximately, in which $d =$ the actual diameter of rivet (in parallel hole); $t =$ thickness of plate. For double-riveted lap-joints: Pitch $= 8t$.

The following rules for rivet spacing apply to bridge and structural work. The minimum center-to-center distance or pitch should not be less than three times the rivet diameter. In bridge work, the pitch should not exceed six inches, or sixteen times the thickness of the thinnest outside plate, except in special cases. The distance between the edge of any piece and the center of the rivet hole should not be less than 1¼ inch for ¾- and ⅞-inch rivets, except in bars less than 2½ inches wide; when practicable, this distance should be at least two rivet diameters for all sizes and should not exceed eight times the plate thickness. For flanges of girders and chords carrying floors, the pitch should not exceed four inches. For plates in compression, the pitch in the direction of the line of stress should not exceed sixteen times the thickness of the plate, and the pitch in a direction at right angles to the line of stress should not exceed thirty-two times the thickness, except for cover plates or top chords and end posts, in which the pitch should not exceed forty times the thickness.

Pitch Point. The term "pitch point" as applied to spur gearing, indicates that point where the line of action intersects the common center line of two gears in mesh.

Pitot Tube. The Pitot tube is used for measuring the velocity of fluids in motion. It consists simply of an open tube having a

right-angle bend. The tube is placed in the stream of water (the pressure of which is to be measured) in such a position that one of the open ends is directed against the flow of the water while the other end projects above the surface of the water. The height to which the water rises in the end projecting above the surface is equal to the velocity head. Modifications of the Pitot tube are also used for measuring the flow of water and gases in pipes.

Pit-Saw File. This type of file is a full half circle in section and is sometimes referred to as a frame-saw. The form is blunt and the teeth single-cut, second-cut. These files are used for filing the teeth of what are known as pit-saws and frame-saws.

Pitting. In boilers, pitting is the formation of conical or spherical depressions in the plates. Pitting is caused by the action of oxygen or chlorine released from the feed water when heated. When the depressions are small and close together, this condition is known as honeycombing. Magnesium and calcium chloride contained in the boiler feed water are frequently the causes of pitting.

Pivot Switches. It sometimes happens that it is necessary to connect a source of power to any one of three or more circuits, and this can be most conveniently done with a pivot switch. A pivot switch is a lever switch having its hinge arranged so it can be revolved around its center, a number of contacts being located on the circumference of a circle with the hinge as its center. With this arrangement, the blade can be closed into any one of these contacts. Pivot switches are usually single-pole, but may be made double- or triple-pole in the smaller capacities. In the latter case, the switches have to be double-break, as the pivot or hinge cannot be a current-carrying part.

Planamilling and Planathreading. The form milling (internal or external) of one or more circular surfaces by a planetary movement of one or more milling cutters mounted on an arbor, is known as *Planamilling*. The work is held by a stationary chuck; the rotating cutters are fed automatically over or through the work to a set stop, and then fed radially into the work to the proper depth of cut; now the cutter arbor travels slowly in a circle and the cutters mill to an accurately finished diameter. When the cutter arbor has made one complete revolution the cutters are automatically lifted from contact with the work and withdrawn while the work is being changed. While this process shows large saving in machine time on a single diameter, greater savings are effected in the simultaneous milling of two or more concentric bores, especially when the innermost bore is larger than the through bore, the machining of which would require

more than one set up on some other type of machine. In *Planathreading* a thread milling cutter of the required pitch is mounted on the arbor and revolved in a circle as in planamilling. The length of the cutter is the same as the axial length of the thread to be cut, plus two threads. While the arbor with the cutter or cutters revolves one revolution, it is also fed axially one thread. One planetary revolution of the arbor completes the operation. Depending on the location of the shoulders of the work, planathreading and planamilling may be performed simultaneously.

Planer. Planing machines are used principally for producing flat or plane surfaces in connection with the finishing of machine parts. The natural function of a planer is to produce plane or flat surfaces, although it is sometimes used for forming irregular or curved surfaces. There are three general classes of planing machines which are commonly known as planers, shapers, and slotters. *Shapers* are smaller machines than planers and are used for lighter work, whereas *slotters*, which might be considered as vertical planing machines, are used for operations that could not be done readily, if at all, on regular planers or shapers. These three classes of planing machines differ radically in their construction. There are several different types of planers which have been designed for planing certain general classes of work to the best advantage. There is, however, what might be called a *standard* design which is found in all machine shops and which is adapted to general planing operations. While the construction or design of planers of different makes varies somewhat, there are certain features which are common to all machines of the standard type.

Open-side Planers: The open-side type of planer has a massive column on one side of the table only so that the opposite side is open and unobstructed, which greatly increases the range of the machine. The cross-rail or beam upon which the tool-heads are mounted is of very rigid design and has a broad bearing surface on the column to prevent deflection due to the thrust of the cut. The chief advantage of an open-side planer is that it can be used for machining large castings which would not pass between the housings of a two-housing planer of ordinary size. The driving and feeding mechanism of an open-side planer is similar, in principle, to that used on the regular type.

Open-side Plate Planer: The open-side plate planer is a type of planing machine designed especially for planing the edges of steel and iron plates. While this machine is known as a *planer*, it is, in reality, a modification of the shaper, since the planing tool is given a reciprocating movement, and the work-table and work remain stationary.

Combination Planer: In shops where the use of an open-side planer would be exceptional, but necessary, at times, what is known as a combination planer has been used to a limited extent. One planer of this class is equipped with two housings which are similar to the housings of an ordinary planer. When the work is too wide to pass between these housings, one is moved back along the bed and a box-shaped casting or brace is interposed between the housing and the cross-rail to support the latter against the thrust of the cut. By adjusting the housing backward in this way, a standard form of planer is converted partially to an open-side type.

Crank Planer: The crank planer, as the name indicates, derives its motion from a crank instead of from a rack and gearing. This crank motion is generally the Whitworth quick-return movement, or some modification of it. Planers of this type are made in small sizes, a 20- by 20- by 24-inch machine representing a typical size. These machines are especially adapted to rapid operation on comparatively short work; in fact, the general class of work is similar to that done on a shaper. The crank planer, as compared with the standard planer, has the advantage that the stroke is definite and exact, owing to the fact that the motion is derived from a crank mechanism; therefore, it is possible to plane right up to a line without the danger of over-running. While the general characteristics of a crank planer are similar to those of the shaper, it differs from the latter in that the work-table moves to and fro, the same as with the regular planer, whereas, in the case of the shaper, the tool itself is traversed back and forth across the work. Owing to the speed and accuracy of a crank planer, it is particularly adapted for tool and gage work.

Traveling-head Planer: Traveling-head planer is the name given a certain type of planing machine that operates on the same principle as a draw-cut shaper, although of very different construction. The planer has a large floor plate for holding the work, and a vertical column upon the face of which is a slide. The latter carries the ram for planing and also the ram operating mechanism. The slide and ram have a vertical adjustment upon the column, the arrangement being similar, in this respect, to a horizontal boring machine of the floor type. As previously intimated, the cutting is done on the return stroke of the ram, so that the thrust of the cut is taken directly by the column. The reciprocating motion of the ram is controlled by two special friction clutches. This planing machine may also be used for milling and boring operations, thus enabling planed parts to be finished complete at one setting, in many instances.

Duplex Planer: The duplex planer differs from the ordinary type in that there are housings (equipped with a cross-rail and

tool-heads) at each end of the planer bed. The housings at one end may be adjusted on the bed for varying the distance between the two sets of planing tools. This type of planer is intended more especially for such work as planing the ends of locomotive connecting-rods. When doing work of this kind, the rod is clamped to the table in such a position that a cut is taken over one rod end when the table is moving in one direction, and the opposite end is planed when the table movement reverses; therefore, when using this machine, there is no idle return period, and the planer table moves at the same speed in both directions, the tools being constantly in operation.

Pit Planer: Planers of this class are intended for very large unwieldy work, such as armor plate planing, etc. They are so arranged that the work remains stationary and the tool-heads, together with the cross-rail and its supporting columns, are given a traversing movement. The vertical columns between which the cross-rail is held are mounted upon parallel beds, one of which extends along each side of the work-table. One make of pit planer intended for armor plate work is equipped with a cross-rail which swivels 90 degrees each way from the vertical, and carries two tool-heads. For cross-planing, one of the two heads can be traversed along the cross-rail.

Breast Planer: Breast planers are a special type used for planing the edges of armor plate or other work that coubl not readily be done, if at all, on a regular planing machine. They are usually built for cross-planing, the planing operation being done by a tool-head which is traversed along a cross-rail. Power may be applied, however, for longitudinal motion, in which case the work can be planed lengthwise, as well as crosswise.

Frog and Switch Planer: Frog and switch planers are so named because they are intended primarily for shops manufacturing switch parts and rail crossings or frogs for railways. They are also adapted for other work, especially of a heavy nature, such as planing large steel forgings, steel castings, etc. Great driving power and extreme rigidity under maximum duty are characteristic features of these planers. Planers of this class usually have an adjustable cross-rail, the same as a standard planer, although some are so designed that the cross-rail can only be located in one of three fixed positions. See also Rotary Planers.

Planer Attachments. While planers ordinarily do not have much auxiliary equipment, there are certain planer attachments which increase the range or capacity of the planer, and others which make it possible to plane special classes of work. Among the planer attachments commonly used may be mentioned the extension tool-head which increases the planer capacity for handling

exceptionally wide work, the floor stand or independent housing which still further increases the planer capacity, index centers for planing parts that require dividing or spacing, and various other attachments such as those for planing curved surfaces, spiral grooves, etc. These special attachments are needed more particularly in shops handling a wide variety of work, and especially those having a rather limited planer equipment.

Planer Net Cutting Speed. The net cutting speed of a planer is equal to the number of feet traversed by the tool in a given time while cutting or planing, and it is less than the speed of the table on the forward or cutting stroke, because of the idle or return period, when no work is being done. The net cutting speed equals the forward cutting speed divided by the total time required for the forward and return movements. If the cutting speed were 40 feet per minute and the return speed 120 feet per minute, a forward movement if continued for a distance of 40 feet would require one minute and the return stroke one-third minute, or 1 1/3 minutes for forward and return strokes. Therefore the number of feet per minute traversed by the tool while actually cutting equals $40 \div 1\ 1/3 = 30$ feet per minute.

Planer Origin. The names of six or seven English inventors are associated with the planer which was used at such an early period in the United States that there may also have been independent developments. The French were, to a certain extent, pioneers as a form of planing machine was invented by Forq in 1751, although the design is not along the lines of the early English types. A planer is said to have been built by Matthew Murray in 1814 in order to machine the D-slide valve for steam engines.

The oldest existing planer is in the South Kensington Museum in London. This planer, in its general principle of operation, resembles the modern type in so far as the relationship of a tool-head and table are concerned. The table is reciprocated by the pilot type of handwheel acting through a sprocket and chain transmission. This chain is of the ordinary forged link type The tool-slide has vertical and horizontal feeding movements, angular adjustment, and a hinged tool-block for lifting during the return stroke. This planer was built by Richard Roberts in 1817, and evidently it was made without the use of a planer as chisel and file marks on the bed and ways indicate hand work.

In 1820, George Rennie built a screw-driven planer which had a revolving cutting tool—an idea evidently considered quite important by several early designers. In this same year, 1820, Joseph Clement built a planer provided with two cutting tools, one being for the forward and the other for the return stroke.

This was known as the "Great" planer and the bed operated on rollers to reduce frictional resistance. It is believed that the first planer in America was built in 1836 in the shop of Silver & Gay Co., North Chelmsford, Mass., although a planer is said to have been built at about the same time by Pedrick & Ayer of Philadelphia.

Planer Size. The size of a planer is equivalent to the width and height of the largest part that will pass between the housings and under the cross-rail, when the latter is raised to its highest position. For instance, a 38- by 38-inch planer is one that will plane work approximately 38 inches wide and 38 inches high. Sometimes the maximum length that can be planed is included when designating the planer size. Thus a 36-inch by 36-inch by 8-foot planer means that a piece 36 inches square will pass between the housings, and that a length of 8 feet can be planed.

Planers, Gear. See Gear Planers of Templet Type.

Planer Tools, Right- and Left-Hand. Planer tools are usually lesignated as right-hand when the cutting edge is on the right-hand side, assuming that the tool is in a horizontal position and is seen from above, whereas left-hand planer tools have the cutting edge on the left-hand side. If a planer tool is in the working position, then, as viewed from the front of the planer, a right-hand tool has its cutting edge on the left-hand side and it feeds from right to left. The foregoing method of designating right- and left-hand planer tools has never been applied universally, but it seems to agree with the most prevalent usage at the present time. It would be preferable, however, in case these names were standardized, to have them agree as to the "hand" for both lathe and planer tools of the same general type or shape. See also Lathe Tools, Right- and Left-hand.

Planetary Gearing. Planetary gearing (also called differential and epicyclic gearing) is the common name for a special type of mechanism used in the transmission of mechanical motion. It is composed of a series of mounted toothed wheels in gear, the distinctive characteristic being that some of the wheels turn on movable centers, while the others turn on fixed centers. Its specific advantage is that it may give very little or very great change in angular velocity with the same or the opposite directional relation, all within very small compass. Usually the change in angular velocity is in the nature of a reduction, and very large reductions are readily obtained. The wheels that turn on movable centers are termed "planet wheels" and those that turn on fixed centers are called "sun wheels."

Planimeter. The planimeter is an instrument used for determining the area of a figure on a drawing or map by moving a

"tracing point" of the instrument along the outline of the area or surface to be measured. The irregular shape of the area does not influence the accuracy of the reading. A common form of planimeter is the "Amsler *polar planimeter*." The results obtained by the planimeter are correct within an error of about one per cent. A more elaborate instrument than the polar planimeter is known as the *rolling planimeter*. This instrument is more expensive than the polar type but results that are correct within 0.1 per cent can be obtained by it. The whole instrument rolls forward and backward in a straight line while the tracing point follows the outline of the surface to be measured. The planimeter is used for measuring areas in general, and especially for measuring the areas of indicator cards. Some forms give the mean effective pressure directly, without computations, by changing the scale to correspond with the spring used in the indicator.

Planishing. A planishing operation is one involving the use of a hardened tool having a very smooth working surface which imparts a fine finish to a steel or other surface by either a rubbing or a rolling process, depending upon the nature of the work. The tool used may either be in the form of a hand-tool having a smooth end which is held into contact with the rotating surface, or it may consist of a hardened and polished roller or of a pair of rolls. In rolling finished shapes in steel mills, the pass next to the last one is called the "planisher," or sometimes the "leader." Planishing rolls are also used for certain finishing operations on sheet metals. For example, the second pair of rolls used for finishing coin metal by cold-rolling prior to minting, are known as planishing rolls. Cylindrical parts which have been turned in the lathe are sometimes finished by rotating in contact with a hardened and polished roller, the object being to obtain a dense surface and a smooth finish. This planishing operation, however, is not common, and is confined largely to certain railroad shops where it is applied to the fitted ends of crankpins and axles. In metal spinning, a "planisher" is used for planishing or burnishing the surfaces of spun parts. This tool is manipulated by hand, and has a hardened and polished end which removes unevenness as it rubs over the rapidly rotating part, the surface of which is made smooth and dense. The term "planishing" is also applied to a hammering operation, which consists in giving parts a dense, smooth finish by a rapid succession of blows delivered by the highly polished dies or hammers of a planishing hammer. Planishing is similar to burnishing so far as the general principle of the process is concerned, and the two terms are used interchangeably for certain operations.

Plano-Milling Machines. Horizontal milling machines of the planer type are sometimes referred to as *plano-milling machines*,

because the general design resembles that of an ordinary planer. When the name "plano-milling machine" is used, it is often applied regardless of the arrangement of the cutter spindles; that is, whether the machine is equipped simply with one horizontal spindle, with vertical spindles on the cross-rail, or with both vertical and horizontal spindles.

Plant Factor. The ratio of the average load to the rated capacity of the power plant, *i.e.*, to the aggregate ratings of the generators, is the plant factor.

Plaskon. A urea-base synthetic plastic molding material obtainable in all colors from white to lustrous black. Infusible and inflammable, tasteless, odorless, resistant to the action of grease and oils, and to the common organic solvents. Compressive strength, 25,000 to 35,000 pounds per square inch; tensile strength, 8000 to 13,000 pounds per square inch. Used for practically all purposes where a synthetic plastic material might be applied, and especially where color is of importance. Covers and cases as large as 15 by 15 by 18 inches have been made.

Plasma. Plasma may be defined as a gas that has been heated until electrically dissociated into positive ions and electrons. It is not simply a hot gas, but is actually a fourth state of matter.

Plasma is formed, for example, within a welding arc as commonly used in the open atmosphere. Plasma temperatures thus obtained are relatively low, about 10,000 degrees F., since the heated air is free to expand. When the arc is constricted to a small cross-sectional area, the plasma temperature may be increased to 40,000 degrees F. or higher.

Plasma-Flame Metal-Spraying. Application of high-temperature refractory materials by the plasma-flame-spray technique is performed using a commercially available plasma-flame-spray gun. Although temperatures ranging from 10,000 to 15,000 degrees F., are adequate for normal spraying of such high-temperature materials as aluminum oxide, tungsten, and tungsten carbides, steady temperatures up to 30,000 degrees F. can be maintained. Despite the extremely high temperatures involved, the sprayed work remains comparatively cool.

Within the gun are two non-consumable, water-cooled electrodes. The inner electrode is pencil-shaped; the outer electrode is the circular, inner end of the nozzle. Almost any inexpensive polyatomic gas—preferably nitrogen to which has been added 5 to 10 per cent hydrogen—is heated by the direct-current electric arc in a confined space and under pressure. The gas is thus ionized to form the plasma within the nozzle. Spray powder,

suspended in a carrier gas (same as plasma gas), is fed into the nozzle from an external tube and enters the plasma flame beyond the arc.

It should be emphasized that the plasma flame is *not* the arc. The arc is confined within the nozzle and does not leave the gun. Long nozzle life can be expected as the arc never actually touches the outer electrode. This is accomplished by the flow of nitrogen through the gun. The high-velocity plasma gas surrounds the arc, pinching it within the nozzle.

Plaster Molds. Plaster-of-paris molds are especially useful as a means of producing small castings for experimental work. A casting made in a plaster-of-paris mold is smoother than one made in a sand mold. Plaster-of-paris alone will not withstand the heat of molten metals, and experience has shown that the addition of asbestos is necessary to insure the success of so-called "plaster-of-paris" molds. Pure plaster would crack when heated, and the castings produced would not be uniform. The percentage of asbestos may be varied according to the material to be cast, although equal amounts of plaster-of-paris and asbestos generally produce very satisfactory results.

The mixing of the plaster is very simple, yet there are several points that require careful consideration. A pan or pail of suitable size is partly filled with water (the amount depending on the quantity of plaster required) and powdered plaster sifted into the water. When the sifted plaster thus piled up reaches the surface of the water, an equal amount of asbestos is added. Care should be taken not to stir the water and plaster-of-paris before adding the asbestos. After the addition of the asbestos the ingredients are stirred thoroughly. The asbestcs is used in pulverized form. A small amount of plaster should be poured on the pattern, and a soft brush used to brush the surface of the pattern over with the plaster before filling up the frame. This insures covering the entire surface and prevents the formation of air pockets.

Wooden and metal patterns should be covered with a coat of oil before pouring the plaster. This facilitates the removal of the pattern from the mold after the plaster has set. A mold of this kind will set in from twenty to thirty minutes. The entire matching surface of the drag is covered with a solution of soapy water, which prevents the plaster forming the cope from adhering to that of the drag.

Plaster-of-Paris. Plaster-of-paris is a calcined gypsum from which the water has been driven off by heat. Plaster-of-paris, when diluted with water into a thin paste, sets rapidly, and at the instant of setting, it expands or increases in bulk. This ma-

terial is, therefore, used for making casts of statuary, etc., as it fills the forms perfectly. It is also used as a pattern material. Plaster-of-paris sets in from three to six minutes, but if, for any reason, it is desired to keep the mass plastic for a longer period, this may be done by adding a drop of glue to a five-gallon mixture. This will keep the plaster-of-paris soft for a couple of hours. Citric acid will also delay the setting of plaster-of-paris for several hours. One ounce of citric acid will delay the setting of one hundred pounds of plaster-of-paris for two or three hours. The acid is dissolved in water before being mixed with the plaster. Plaster-of-paris, when mixed with cold water, has an expansion of about 1/16 inch to the foot when hardening. If this expansion is undesirable, it may be mixed with warm water or lime water, in which case the expansion is negligible. When mixing plaster-of-paris, water should not be poured on the plaster, but the plaster should be sprinkled into the required amount of water until it sets as a powder upon the surface of the water. Then it should be stirred quickly by hand until the mass attains the consistency of heavy cream, when it is ready for use.

Plasticalk. A plastic compound taking the place of putty and similar substances, which does not dry, harden, crack, or shrink with age, but retains its plasticity and adhesiveness indefinitely. It is unaffected by water and humidity and adheres strongly to the substances that it joins. Used for cementing glass to glass, metal, or wood; for calking crevices; and for making joints of various kinds. Especially useful in the marine field, for refrigerator show-cases, etc.

Plastic Bronze. Plastic bronze is an alloy containing 69 per cent of copper, 10 per cent of tin, and 21 per cent of lead. This alloy may be used as a bearing metal.

Plasticity. Plasticity is the ability of a metal to be permanently deformed without breaking.

Plastics. Synthetic plastics of various kinds are now a very important engineering material and are used for numerous structural parts in many lines of manufacture. The advantages obtainable with plastic materials may be divided into two groups. The consumer advantages include light weight (half the weight of aluminum); a chip-proof, scuff-proof luster; non-resonance; non-conductance of electricity; pleasing-to-touch surface; and resistance to peeling, checking, moisture, heat, acids, alkalies, and greases. The engineering advantages are self-insulation; lower shipping weight; elimination of grinding, spraying, and baking operations; reduction of finish rejections and damage to finish in shipping; and when the quantities are sizable, produc-

tion economy—all of which may result in lower costs. In many instances, there are both lower production costs and convincing sales arguments.

In the use of plastics, it is important to select material that is adapted to a given application and the manufacturers should be consulted. To show some of the varieties of phenolic molding materials available, the major groupings of one supplier are listed:

General Purpose	Closure Type
Non-bleeding	Moisture-resistant
Heat-resistant	High Dielectric
Extrusion Type	Acid-, Alkali-resistant
High Impact	Friction-resistant
Arc-resistant	Sanding, Buffing Type

Synthetic plastic materials are now being used in almost every type of industry for one purpose or another. They are available in practically all colors and for almost all purposes where metal can be used, except where a very high degree of strength is required. They are lighter in weight than any common metals and are sufficiently hard to take the place of metal parts for most purposes. Transparent, translucent and opaque materials are available. Another important development in the field of synthetic plastics is the greatly increased use of bar stock for the production of a wide variety of objects by lathes and automatic screw machines. Synthetic plastics are made in the form of rods, tubes, sheets, and castings.

Plastics are usually divided into two general classes. The "thermo-setting" or "thermo-reactive" plastics undergo a chemical change when heated to the curing temperature in the mold. This change usually results in permanent hardening and in making the material infusible and insoluble. It is, therefore, irreversible. The "thermo-plastic" plastics do not undergo a chemical change when molded. They are merely softened by the application of heat and solidify again when cooled below a certain temperature. Moldings made from this type of material can be remolded again when heated.

Plastic Set. See Permanent Set.

Plastics, Properties. The relative values of some of the more important plastic materials in terms of various properties are indicated by the following numbers. For each property No. 1 represents first choice, No. 2 represents second choice and so on. This information has been obtained from the Bakelite Corporation.

Toughness (Impact Strength): 1. Aceto-Butyrate; 2. Shock-Resistant Phenolic; 3. Ethyl-Cellulose; 4. Cellulose-Acetate; 5. Vinyl; 6. Methyl-Methacrylate; 7. Polystyrene, Transparent Phenolic; 8. Low-Loss Phenolic; 9. Urea; 10. General Purpose Phenolic, Heat-Resistant Phenolic; 11. Acid and Alkali-Resistant Phenolic.

Flexural Strength: 1. Urea, Transparent Phenolic: Vinyl (No Filler), Methyl-Methacrylate, Shock-Resistant Phenolic; 2. Ethyl-Cellulose; 3. General Purpose Phenolic, Low-Loss Phenolic; 4. Heat-Resistant Phenolic, Polystyrene; 5. Aceto-Butyrate; 6. Cellulose-Acetate, Acid and Alkali-Resistant Phenolic.

Tensile Strength: 1. Urea; 2. Vinyl (No Filler); 3. General Purpose Phenolic, Transparent Phenolic; 4. Methyl-Methacrylate; 5. Shock-Resistant Phenolic; 6. Ethyl-Cellulose; 7. Low-Loss Phenolic, Polystyrene; 8. Heat-Resistant Phenolic, Acid and Alkali-Resistant Phenolic; 9. Cellulose-Acetate; 10. Aceto-Butyrate.

Cold Flow (Relative per cent decrease in height of ½-inch cube in 24 hours under load of 1,000 pounds and at 120 degrees Fahrenheit): 1. Phenolic (All Types Applicable), Urea; 2. Vinyl; 3. Polystyrene; 4. Methyl-Methacrylate; 5. Cellulose-Acetate.

Heat Resistance (Highest Temperature for Use): 1. Heat-Resistant Phenolic; 2. General Purpose Phenolic; 3. Shock-Resistant Phenolic, Transparent Phenolic, Low-Loss Phenolic, Acid and Alkali-Resistant Phenolic; 4. Aceto-Butyrate; 5. Cellulose-Acetate, Ethyl-Cellulose; 6. Polystyrene; 7. Urea; 8. Vinyl; 9. Methyl-Methacrylate.

Heat Conduction (Thermal Conductivity): The following materials are listed in order from poorest to best: 1. Polystyrene; 2. General Purpose Phenolic, Transparent Phenolic, Acid and Alkali-Resistant Phenolic, Vinyl, Methyl-Methacrylate; 3. Shock-Resistant Phenolic; 4. Cellulose-Acetate, Ethyl-Cellulose; 5. Urea; 6. Aceto-Butyrate; 7. Heat-Resistant Phenolic, Low-Loss Phenolic.

Flammability (Inverse ratio of the time a piece continues to burn after removal from gas flame): 1. Heat-Resistant Phenolic, Low-Loss Phenolic; 2. Acid and Alkali-Resistant Phenolic, Transparent Phenolic; 3. General Purpose Phenolic; 4. Shock-Resistant Phenolic; 5. Urea; 6. Polystyrene, Aceto-Butyrate, Cellulose-Acetate, Ethyl-Cellulose, Vinyl, Methyl-Methacrylate.

Water Absorption (Immersion A.S.T.M.): The following materials are listed in order from lowest to highest: 1. Polystyrene; 2. Vinyl; 3. Heat-Resistant Phenolic, Low-Loss Phenolic; 4. Transparent Phenolic, Acid and Alkali-Resistant Phenolic; 5. Methyl-Methacrylate; 6. General Purpose Phenolic; 7. Shock-Resistant Phenolic; 8. Aceto-Butyrate; 9. Urea; 10. Ethyl-Cellulose; 11. Cellulose-Acetate.

Acid Resistance: 1. (Excellent for both weak and strong acids) Polystyrene, Vinyl; 2. (Very good for weak acids and good for strong acids which are not oxidizing) Acid and Alkali-Resistant Phenolic, Transparent Phenolic, Methyl-Methacrylate; 3. (Fair to weak acids and good to strong acids which are not oxidizing) General Purpose Phenolic; 4. (Fair to weak acids and poor to strong acids) Heat-Resistant Phenolic, Shock-Resistant Phenolic, Urea, Cellulose-Acetate, Ethyl-Cellulose, Aceto-Butyrate.

Solvent Resistance: 1. Phenolics: All Types (Bleeding of color only encountered on some), Urea; 2. Vinyls, Polystyrene; 3. Methyl-Methacrylate, Cellulose-Acetate, Ethyl-Cellulose.

Caustic Resistance: 1. (Excellent for weak and strong caustics) Polystyrene; 2. (Very good for weak and strong caustics) Vinyl, Methyl-Methacrylate, Ethyl-Cellulose; 3. (Very good for weak and poor for strong caustics) Acid and Alkali-Resistant Phenolic, Transparent Phenolic; 4. (Fair for weak and poor for strong caustics) Urea, Aceto-Butyrate, General Purpose Phenolic, Low-Loss Phenolic, Heat-Resistant Phenolic; 5. (Fair for weak and very poor for strong caustics) Shock-Resistant Phenolic; 6. Cellulose-Acetate.

Dimensional Change after Molding: The following materials are listed in order from lowest to highest. 1. Heat-Resistant Phenolic; 2. Low-Loss Phenolic; 3. Polystyrene, Vinyl; 4. General Purpose Phenolic; 5. Acid and Alkali-Resistant Phenolic, Transparent Phenolic; 6. Shock-Resistant Phenolic; 7. Urea; 8. Ethyl-Cellulose, Methyl-Methacrylate, Aceto-Butyrate; 9. Cellulose-Acetate.

Weight per Unit Volume: The following materials are listed in order from lightest to heaviest. 1. Polystyrene; 2. Ethyl-Cellulose; 3. Methyl-Methacrylate; 4. Aceto-Butyrate; 5. Acid and Alkali-Resistant Phenolic; 6. Transparent Phenolic; 7. Cellulose-Acetate; 8. General Purpose Phenolic; 9. Vinyl; 10. Shock-Resistant Phenolic; 11. Urea; 12. Low-Loss Phenolic; 13. Heat-Resistant Phenolic.

Hardness (Brinell): 1. Urea; 2. Heat-Resistant Phenolic; 3. Low-Loss Phenolic; 4. Acid and Alkali-Resistant Phenolic, Transparent Phenolic; 5. General Purpose Phenolic, Shock-Resistant Phenolic; 6. Polystyrene; 7. Methyl-Methacrylate, Vinyl; 8. Aceto-Butyrate, Ethyl-Cellulose; 9. Cellulose-Acetate.

Dielectric Strength (A.S.T.M. ⅛-inch Instantaneous): 1. Urea, Ethyl-Cellulose, Vinyl; 2. Polystyrene, Methyl-Methacrylate; 3. Low-Loss Phenolic; 4. General Purpose Phenolic; 5. Cellulose-Acetate; 6. Transparent Phenolic; 7. Acid and Alkali-Resistant Phenolic; 8. Heat-Resistant Phenolic, Shock-Resistant Phenolic.

Relative Loss Factor: The following materials are listed in order from lowest loss to highest loss. 1. Polystyrene; 2. Ethyl-

Cellulose; 3. Aceto-Butyrate; 4. Low-Loss Phenolic; 5. Methyl-Methacrylate; 6. Vinyl; 7. Transparent Phenolic; 8. Cellulose-Acetate; 9. Urea; 10. General Purpose Phenolic.

Plastic Wood. A material known as plastic wood is so called because it is sufficiently plastic to be molded readily with the fingers and it may be used for filling cracks, holes or other defects. It hardens quickly and then can be carved, planed, sand-papered, or turned in a lathe the same as ordinary wood. This material is transported and sold in cans. The manufacturers claim it will adhere to metal, tile, cloth and glass, as well as to wooden surfaces, and that nails and screws will not split it. It may be painted, stained or varnished and has the general characteristics of wood, except that it has no grain. Plastic wood may also be used for filling defects in castings, provided improvement in appearance is the only requirement.

Plate Gage. See Gages for Sheet Metals.

Platelustre. A baking enamel by means of which any polished metal can be made to resemble brass, aluminum, or steel. Flat stock finished with the enamel can be formed after baking. The enamel can be applied to polished metal by spraying or roller-coating. Especially suitable for use in the manufacture of lighting fixtures, compacts, novelties, and other products on which a brilliant metallic finish is desirable.

Platen. This is a name frequently applied to the table of a planer and to the work-holding tables of hydraulic presses, testing machines and certain other classes of mechanical equipment.

Platine. The white-metal alloy platine is composed of 43 per cent of copper and 57 per cent of zinc.

Plating, Chromium. See Chromium Plating.

Platinite. A nickel steel containing 42 per cent of nickel has the same coefficient of expansion as glass. It is known as *platinite,* because the only other metal that has this coefficient of expansion is platinum. Both platinum and platinite have been employed in the incandescent lamp for the connecting wire fused into the glass to establish an electric connection between the inside and outside of the bulb. Platinite is used for scientific instruments or for standards of length, because of its peculiar quality of being practically non-expansive when heated to high temperatures.

Platinoid. Platinoid is an alloy containing 60 per cent of copper, 14 per cent of nickel, 24 per cent of zinc, and 2 per cent of tungsten. The name is derived from the fact that it possesses some of the properties of a platinum alloy.

Platinum. Platinum is a grayish-white metal which is very malleable and ductile. This is one of the heavier metals, having a specific gravity varying from 20.85 to 22.6, according to the treatment it has received. It melts at a temperature of 1755 degrees C. (3190 degrees F.). Its linear expansion per unit length, per degree F., equals 0.00000479. Its electrical conductivity (silver = 100) is about 14.4. Its mean specific heat, from 32 to 212 degrees F., is 0.0323. Its latent heat of fusion is 27.18 calories. The atomic weight is 195.2.

Plioform. Thermoplastic material which molds into relatively hard forms rapidly and without vulcanizing. Obtainable in almost any color, except very light shades. Lends itself to the production of many decorative effects—plain, variegated, or mottled. Because of its comparatively low cost, is suitable wherever decorative effects are desired.

Plioweld. A rubber lining material, about 3/16 inch thick, which provides effective protection against most corrosive liquids, hot and cold; does not oxidize nor crack or buckle under conditions of alternate drying and wetting. Used for the protection of steel, aluminum, lead, or wooden tanks. A special adhesive derived from rubber actually "welds" the resilient rubber to the tank walls during the process of vulcanization.

Plow Bolt. This is a general name for a number of types of bolts employed in the making of plows and cultivators. They are generally short bolts with a countersunk head and provided with a square nut.

Plow Steel. The term "plow steel" is a commercial trade name applied to a high grade open-hearth steel used in making wire rope. The name originated in England because of the application of a strong grade of steel wire to ropes used in the mechanical operation of plows.

Plow-Steel Wire. Plow-steel wire is a special kind of very high-grade steel wire having an ultimate strength varying from 200,000 to 350,000 pounds per square inch, according to the diameter of the wire. For wire 0.093 inch in diameter, the tensile strength has been found to be as high as 345,000 pounds per square inch, whereas, for wire 0.191 inch in diameter, the strength is about 200,000 pounds per square inch. The elongation is only about 1 per cent. The composition of the wire is about as follows: Carbon, 0.83 per cent; manganese, 0.59 per cent; silicon, 0.14 per cent; sulphur, 0.01 per cent; phosphorus, nil; copper, 0.03 per cent.

Plug Fuse. The most common type of fuse is the plug fuse which is generally used to provide protection against overloading

of 110- to 125-volt lighting circuits. These fuses are very compact and consist of a cylindrical porcelain or composition body in which the fuse strip is placed. They fit into lamp-type receptacles in a porcelain cutout base. Most types are non-renewable, but at least one design provides for renewed use by switching a succession of new fusible elements into the circuit. They are limited to a 250-volt, 30-ampere rating.

Plug Switches. In a plug switch, the stationary contacts are known as "receptacles" and the bridging member as the "plug." Plug switches may be arranged in either of two ways; the receptacles may be placed one back of the other and the circuit completed by inserting the plug so that it will pass through the first receptacle and into the second; or the receptacles may be placed side by side, and two plugs, connected at their outer ends, inserted to complete the circuit. There are many forms of plug switches, each designed to meet certain conditions.

Plumbago. Plumbago, also commonly known as "black lead," is a name frequently applied to a certain quality of graphite. Plumbago is used in the foundry, for the "blackening" of molds, and mixed with tallow and wax as a lubricant for driving ropes. The main supply of plumbago imported into the United States comes from Ceylon.

Plunge-Cut Grinding. This term has been applied to grinding which is done by directly feeding into the work a wheel, the face of which is sufficiently wide to cover the entire surface being ground. In the case of parts with surfaces longer than the maximum possible wheel face, the grinding is done by in-feeding along the work at successive intervals, the face of the wheel overlapping slightly each previous cut, until the grinding of the entire length has been done, after which the work is rapidly moved past the wheel to complete it. This method is adapted to the simultaneous grinding of duplicate parts that can be placed in a gang on a mandrel or other convenient chucking device, such as piston rings, ball-bearing cups, roller-bearing cups, collars, and bushings. Single pieces which lend themselves to the application of a wide wheel are also ground in quantity by this method, such as, for example, transmission shafts, axle shafts, propeller shafts, armature shafts, spindles, pistons, etc.

Pluramelt. The name applied to a steel-making process which makes it possible to produce a single ingot consisting of a low-cost base metal as the chief material and a corrosion-resistant coating of stainless steel or a covering of some other metal. The results are accomplished by means of a special electric arc melting furnace, in which, briefly, all the special-composition material and the surface of the low-cost material are melted and

integrally joined as part of the operation. The furnace is radically different from the conventional type of electric furnace in that the functions of steel making and of ingot mold are combined to produce Pluramelt ingots.

Pneumatic Chuck. This is an air operated chuck used on some turret lathes for holding and rotating work to be machined. The pneumatic operation permits closing and opening of the chuck jaws rapidly.

Pneumatic Hammers. The pneumatic hammer is a combination of a cylinder, a reciprocating plunger or piston, a valve for automatically controlling the movements of the plunger, and a throttle valve for regulating the flow of air to the hammer from the supply pipe. The first practical pneumatic hammer was developed by Boyer of St. Louis, who, in 1883, patented a chipping machine having a handle or grip and a hand-controlled throttle.

Pneumatic Tire. The pneumatic tire was patented in England by R. W. Thomson in 1845. It was not intended originally for the bicycle, but such application was made in 1889 by Dunlop, as covered by a United States patent granted in 1890.

Poisson's Ratio. If a square bar is stressed in a testing machine in the direction of its length, so that the length increases, there is a contraction in each opposite direction, which produces a decrease in the thickness of the bar. The ratio between the contraction at right angles to a stress and the direct extension is called Poisson's ratio. For ordinary kinds of steel this has a value of about 0.3. If the direct stress is a compressive stress, so as to cause decrease of length in the direction of the stress. then there will be an expansion in each direction at right angles equal to 0.3 times the compression.

Polar Moment of Inertia. The polar moment of inertia of a surface is the moment of inertia with respect to an axis through the center of gravity at right angles to the plane of the surface, and equals the sum of two moments of inertia taken with respect to two gravity axes in the plane of the surface at right angles to each other. The *polar section modulus* equals, for circular sections, the polar moment of inertia divided by the distance from the center of gravity to the most remote fiber. This method may also be applied with fair accuracy to sections that are nearly circular. For other cross-sections, the polar moment of inertia has been obtained in the form of empirical formulas by means of experiments.

Polar Section Modulus. The polar section modulus is also known as the section modulus of torsion. See Polar Moment of Inertia.

Polarization. Polarization is a phenomenon which occurs on the passage of a current between two electrodes immersed in an electrolyte, and its effect is to oppose the flow of current by creating a counter-electromotive force. The discharge voltage is equal to the cell potential, as it would be without external load, minus internal resistance drop, minus the polarized counter-electromotive force. The charging voltage is equal to the cell potential (without external load), plus internal resistance drop, plus the polarized counter-electromotive force.

In the case of dry cells, polarization is commonly understood to mean the formation of a layer of hydrogen at the carbon electrode which takes place when the circuit is closed. This layer of hydrogen practically constitutes a new pole in place of the carbon electrode but it has no charge since this is delivered to the carbon electrode when it comes in contact with it. As polarization develops, the zinc electrode gradually loses its charge by delivering it to the carbon pole through the external circuit. Hence, there comes a time when the hydrogen layer completely covers the carbon electrode, there ceases to be any potential difference between the zinc and copper poles and the flow of current ceases. See also Depolarizer.

Polaroid. A transparent material similar to glass, known as "Polaroid," is used the same as glass but "polarizes" light and makes it possible to obtain remarkable results. For example, when Polaroid is used in the headlights of automobiles, as well as in the windshield of an approaching car, there is no glare from the fully turned on headlights. By the use of this new "glass" it is possible to produce three-dimensional movies. When used in connection with color photography, the actors virtually come to life, moving no longer merely across a screen, but apparently on a stage for which the outline of the screen seems to form a frame. To get this effect, the pictures must be viewed through spectacles provided with Polaroid. By this means, colors become realistic and objects stand out as if they were actually placed on a stage.

In engineering, this new polarized glass has an important function. It enables models made from transparent materials, such as synthetic plastics, to be used to examine the stresses in engineering structures, or, in fact, in all kinds of industrial products; furthermore, products transparent in themselves, like glassware, when viewed through Polaroid, will portray strains left by the manufacturing processes through the brilliant colors that the strained portions assume. Colorless cellophane may be given brilliant colors of every hue for display signs, stage decoration, architectural ornaments, and other purposes, simply by placing clear colorless cellophane between two sheets of the new material.

By rotating one of the Polaroid plates, the colors are made to constantly change. Colorless sun glasses made of Polaroid will eliminate the glare of the sun, leaving the view unchanged. This material is adapted to many additional applications in science and industry.

Pole Lathe. The pole lathe, which was a primitive form, consisted of two poppets supported on a wooden bed, and suspended from the ceiling was a wooden spring-pole, to the free end of which was attached a strong cord. This cord was wound once around the piece to be turned, and the loose end was carried down to the floor where it was formed into a loop for the workman's foot. In improved forms of the pole lathe, a rude treadle was provided instead of the loop. When the foot was depressed, the work-piece was turned by the cord against the cutting tool, the spring-pole depressing at the same time. With the upward lift of the foot, the spring-pole raised the cord and turned the work in the opposite direction. The pole lathe had the serious objection that the work did not turn continuously, but was turned alternately in opposite direction. A very high degree of skill was required to do satisfactory work, as the turning tool had to be lifted the moment the work began to turn backwards, and had again to be brought to the cutting position when the reverse movement began; hence, the application later of a driving wheel connected by a cord to drive the work continuously in one direction. The driving wheel, which was turned by a crank, was mounted on a separate stand or base placed to one side of the lathe, and was usually provided with three grooves. This type of machine required two workmen, one to turn the crank and the other to handle the cutting tool.

Polishing. In general polishing is an operation performed by using any wheel that has a polishing abrasive glued to its face, regardless of whether the wheel is made from leather, canvas, or some other material. The term polishing embraces everything from the "flexible-grinding" operations performed on rough forgings such as axes and picks, and the removal of flash from table knives and forks, to the production of the brightest luster, such as is given to surgical instruments, high quality scissors, and other kinds of general hardware. The former class of work, which consists of grinding away metal preliminary to the luster producing process, has been called "flexible grinding." This term is also applied to other operations in which a flexible polishing wheel removes metal preparatory to plating, painting or enameling the surface. In contradistinction to flexible grinding is the process by which the surface of metals is refined by a number of

operations until it has been reduced to a degree of smoothness that is known as a mirror finish; that is, a finish such that the light is refracted from the surface as in a mirror. But in general, in the trade, polishing is the term used to cover all this work of refining metal surfaces. Polishing, however, does not include buffing which is done with cloth wheels to which the abrasive is applied loosely instead of imbedding it in glue. See Buffing.

Polishing wheel speeds vary somewhat for different kinds of work, but ordinarily the speed at the periphery of the wheel ranges from 6000 to 7500 feet per minute. Loose muslin wheels of the kind used for buffing often run at from 8000 to 10,000 feet per minute.

Polishing or Buffing Machines. The type of machine that is generally used for polishing and buffing operations is usually known either as a polishing or buffing lathe, machine, stand, or head. It is very simple in construction and consists simply of a column and a spindle which is mounted in suitable bearings and provided with means for holding the polishing or buffing wheels. This spindle is rotated very rapidly when the machine is in use, and the wheels are held either between the collars shown or on a tapering screw at the end of the spindle.

Some polishing machines are equipped with polishing belts. The belts used on machines of this type may be of cotton, felt, leather, or abrasive cloth. When plain cloth or leather belts are used, they are prepared for polishing by first applying a coat of glue and then a suitable abrasive to the working surface. Machines of the belt or band type are sometimes provided with a flat supporting plate back of the point where the work is applied to the belt, so that the machine is adapted for polishing flat surfaces.

Some machines are designed to automatically maintain contact between the work and the polishing or buffing wheel so that the entire surface is finished without hand manipulation. Circular parts rotate while in contact with the wheel and a reciprocating device may be used to provide a traversing movement. With square, hexagonal, oval, or unsymmetrical parts, the distance from the center of the work to points along the outside varies considerably, and so a special mechanism must be employed to change the distance between the center of the buffing wheel and the center of the work as the work is revolved. Some machines which automatically present the work to the wheel have multiple-spindle work-heads. With such a machine, the operator loads and removes the work while contact of the work and buffing wheel is made automatically by the intermittent indexing of the work-head.

One type of automatic polishing machine intended for fairly flat parts has a feed belt which carries the parts under a series of polishing wheels. Pieces up to several inches in thickness may be handled, and the machine is built in various widths to accommodate pieces up to about 20 inches wide. Contact between the work and the polishing wheels is maintained by a micrometer adjustment. The machine is built in units, each of which carries an independently operated polishing wheel that is driven by an individual motor. Any number of units may be used in one battery to suit the particular polishing process or desired rate of production.

Polygons. A polygon is a plane geometrical figure bounded by a number of straight sides. Strictly speaking, triangles and figures having four sides are *polygons*, but the term is more generally applied to figures having more than four sides. If all the sides are of equal length and the angles between the sides are equal, the figure is called a *regular* polygon.

A circle may be drawn so that it passes through all the corners of a regular polygon; such a circle is said to be circumscribed about the polygon. A smaller circle drawn tangent to the sides of the polygon, is said to be inscribed in the polygon. The centers of the circumscribed and inscribed circles are located at the same point. If lines are drawn from this point to the corners it will be found that the polygon is divided into a number of triangles of equal size and shape. An angle, designated by the Greek letter α, equal to one-half the angle between any two adjacent lines meeting at this center point is used in the general formulas which follow. These formulas apply to all regular polygons:

$$A = \frac{N \times \cot \alpha \times S^2}{4} = N \times \sin \alpha \times \cos \alpha \times R^2$$

$$= N \times \tan \alpha \times r^2$$

$$R = \frac{S}{2 \sin \alpha} = \frac{r}{\cos \alpha}$$

$$S = 2R \times \sin \alpha = 2r \times \tan \alpha$$

$$r = \frac{S \times \cot \alpha}{2} = R \times \cos \alpha$$

where N = number of sides; S = length of a side; R = radius of circumscribed circle; r = radius of inscribed circle; A = area of polygon; and $\alpha = 180° \div N$.

Polyphase Circuit. By definition, a polyphase circuit is a group of associated current paths (usually interconnected) which is energized by a set of alternating electromotive forces, all of

which have the same period but which differ in phase.

Two-phase circuits have two single-phase electromotive forces which have a 90-degree difference in phase. The three-wire, two-phase circuit has two separate outgoing wires but a common return wire. The voltage between outside wires is 41 per cent greater than that between either outside wire and the return wire, while the current in the return wire is 41 per cent greater than that in either outside wire. The four-wire, two-phase circuit has two pairs of conductors, the potential differences between each pair being displaced from each other by a phase difference of 90 degrees. A two-phase, five-wire circuit comprises five conductors, four of which are connected as in a four-wire, two-phase system, the fifth being connected to the neutral points of each phase and is usually grounded.

Three-phase circuits have three electromotive forces which differ in phase by 120 degrees. There are three-, four-, and six-wire three-phase circuits, the three-wire being the most extensively used.

Six-phase circuits are used for substation inside connection.

Poppet Valve. The term "poppet valve" is applied to a valve having, ordinarily, a conical surface which engages a conical seat of corresponding angle, thus forming a tight joint by metal-to-metal contact. The valve is usually made of steel or brass and the seat of cast-iron. The nominal valve diameter equals the port diameter. Poppet valves and valve seats should have an included angle of 90 degrees, the valve seat and corresponding bearing surface on the valve inclining 45 degrees from the axis or center line.

Poppet Valve Lift. Conical-seated poppet valves require a lift varying from one-fifth to one-fourth greater than corresponding flat-seated valves. Assume that D equals the minimum diameter of the valve seat; d equals diameter of pipe to which valve opening must correspond; and r equals $D \div d$. Then the left may be determined as follows: *Flat-seated Valves:* If $r = 1$, the lift $= D \times 0.25$; if $r = 1.25$, lift $= D \times 0.160$; if $r = 1.5$, lift $= D \times 0.111$; if $r = 2$, lift $= D \times 0.162$; if $r = 2.5$, lift $= D \times 0.040$. *Cone-seated Valves of 45-Degree Angle:* If $r = 1$, lift $= D \times 0.307$; if $r = 1.25$, lift $= D \times 0.205$; if $r = 1.5$, lift $= D \times 0.146$; if $r = 2$, lift $= D \times 0.084$; if $r = 2.5$, lift $= D \times 0.055$. Since flat-seated valves generally introduce a certain amount of wire drawing of the incoming charge, a slight increase over the theoretically correct lift should be provided. This allowance seldom exceeds 25 per cent of the theoretical lift.

Porcelain. Porcelain is an insulating material composed of kaolin, ball clay, flint and feldspar. The characteristics that give

porcelain its value to the electrical industry are as follows: High insulating value; a vitrified structure which resists the entrance of water or moisture; refractoriness; resistance to oils and vapors; freedom from tendency to warp, weaken or deteriorate in any way with age or severe service conditions; attractive appearance; ease of forming into various intricate shapes which are made permanent by firing; mechanical strength, with the exception of resistance to impact; and comparative cheapness.

So called *wet process* porcelain is non-porous and usually provided with a glazed surface. It is used for outdoor high-voltage insulators.

So called *dry process* porcelain is porous and not generally suitable for out-of-door or high voltage insulating use. It is used in the manufacture of knobs, tubes and cleats, bases for lamp receptacles and as a refractory electrical insulation.

Port. A port as the term is applied to mechanical devices, is a passageway as in a cylinder or valve. In a steam engine or air compressor, the ports are the openings for the inlet or exhaust of the steam or air. The port for the inlet in a steam engine is known as the steam port and that for the outlet as the exhaust port. In an air compressor, the port for the inlet is known as the inlet port and the port for the outlet as the discharge port.

Portable Drills. See Drills, Portable Air-driven; and Drills, Portable Electric.

Portland Cement. Portland cement is a chemical compound of lime and silica and lime and alumina, which combines with water when mixed with it, forming substances of great mechanical strength capable of adhering firmly to stone and sand and, hence, forming a valuable building material. The specific gravity is about 3.1. A satisfactory Portland cement when mixed with water will not develop an initial set in less than thirty minutes, and will not develop a hard set in less than an hour, but it must set hard in less than ten hours.

Positive Clutch. This is a clutch for transmitting power between two machine members, the driving and driven members of which are connected by the engagement of interlocking teeth or projecting lugs, so that there is no slippage, the power being transmitted in a positive manner. This type of clutch is employed when a sudden starting action is not objectionable, and when the inertia of the driven parts is relatively small. The teeth of positve clutches are made in a number of different shapes, according to the service for which they are required.

Positive Prints. Processes have been developed for obtaining positive prints directly from the positive originals in reproducing

tracings. These positive prints may have black, blue or dark red lines on a white background. The object in obtaining positive prints is to make reading and checking easier and in addition the white background facilitates the writing of notes.

The Bruning BW Process: With this process a black and white positive print is obtained directly from a positive original or without the use of a negative. The first step consists in exposing the BW paper and the original tracing in a printing machine the same as in making an ordinary blueprint. The exposed paper is then developed by applying a thin film of developing solution. When the print emerges from the machine or attachment, it is a fully developed black and white positive and is ready for use. The BW paper is made especially for this process.

Ozalid White Printing Paper: This process produces dark lines on a white background but by means of dry development or without the use of developing liquids. A heater vaporizes an ammonia solution, thus causing ammonia vapors to rise. The sensitized print material is developed by these vapors.

Transparent Duplicates: Ozalid transparent duplicates, from which an unlimited number of subsequent prints can be reproduced, are made in the same manner as standard ozalid working prints. Additions or changes may be made readily on these transparent duplicates using either pencil or ink. A transparent duplicate thus revised constitutes a new original that is easily obtained. Furthermore, white prints incorporating such revision or changes may be obtained from the altered transparent print even though the original drawing remains unchanged.

Positive Transmissions. Any type of drive or transmission that is unyielding and dependent upon the positive contact of intermeshing teeth or other parts, rather than frictional resistance, is classed as positive. Intermeshing gears represent a positive drive, whereas friction gearing is an example of a transmission that is not positive. In general, slippage between driving and driven members of a positive drive could not occur without breakage or possibly excessive distortion or displacement of the driving and driven members. On the contrary, any transmission that is not positive might slip (and without injury to the mechanism) whenever the load exceeds the frictional resistance between driving and driven surfaces. Most mechanisms are positive either because the power to be transmitted would be excessive for a non-positive drive or because a definite relation must be maintained between the driving and driven members. In many cases, a positive drive is needed to meet both of these requirements.

Positron. A positron is an elementary particle similar in mass but opposite in charge to an electron. This means it has a positive charge of 4.8×10^{-10} electrostatic unit or 1.6×10^{-19} coulomb, and a mass approximately equal to 9.1×10^{-28} gram, which is about 1/1836 the mass of a proton or neutron.

A positron is created as the result of the decay of heavier particles of matter and does not exist long when surrounded by other matter since, sooner or later, it collides with an electron and is annihilated. When an electron and a positron collide, photons—indivisible quantities of electromagnetic energy are produced.

Pot Annealing Furnace. This is a furnace used, in connection with the production of cold-rolled sheet steel, for annealing the coils of sheet metal. The coils are placed in clay pots and packed with fine iron borings, after which a cover is put on the pot and the joints sealed with fireclay. The pot with the steel is then heated in the furnace for about six hours, after which it is withdrawn and allowed to stand for sufficient length of time to become quite cool before the cover is taken off.

Potassium. Potassium is a metallic chemical element, the symbol of which is K, and the atomic weight, 39.10. Pure potassium is a white metal of silvery appearance, having a slightly bluish tint. It combines rapidly with the oxygen in the air, and is at once covered with a film of oxide, if exposed to the atmosphere. Absolutely dry oxygen, however, has no action upon it. At a temperature below 32 degrees F., the metal is fairly hard and brittle, but at ordinary room temperature it is so soft that it can be cut with a knife. Its specific gravity is 0.87 (its weight per cubic inch being 0.031 pound). It is the lightest metal known, with the exception of lithium. It melts at a temperature of 62 degrees C. (144 degrees F.), and boils at a temperature of 667 degrees C. (1233 degrees F.). Its specific heat is 0.166 at 32 degrees F., and its electrical conductivity (silver = 100) is 19.62. Potassium is the basis of all potash salts or compounds. Combined with oxygen, it forms potassium oxide (K_2O), commonly known as "potash."

Potassium Cyanide. See Cyanide.

Potential Energy. Potential or stored energy may be defined as stored-up capacity for performing work. It is measured in the same units as work; that is, in foot-pounds. Potential energy is exemplified in the case of a body of water stored in a reservoir, which would be capable of doing work if released and applied to a turbine. The measure of potential energy is obtained by mul-

tiplying the weight of the stored body by the distance through which it would fall. Potential energy is used in distinction to *actual* or *kinetic* energy, which is the energy of a moving body and is capable of performing work against a retarding resistance.

Potentiometer. A potentiometer is an electrical instrument used for the accurate measurement of currents, voltages, and resistances. It does this by comparing or balancing an unknown electromotive force or potential difference against a known electromotive force or potential difference, using a circuit or network of accurately calibrated resistances, if a direct-current instrument, and of inductances and capacitances as well, if an alternating-current instrument.

Potentiometer Pyrometer. The type of pyrometer which has a potentiometer differs from the millivoltmeter type in that the indicating instrument operates upon a different principle. Instead of utilizing the current to displace either a suspended or pivoted part, the electromotive force of the thermo-couple is opposed by an electromotive force of known value usually derived from a dry cell contained in the instrument. When the balance between the opposing forces is complete, a galvanometer is used to show that no current is flowing, and then the electromotive force of the thermo-couple is indicated directly by the position of a movable contact. The potentiometer requires some outside source of current, but it gives accurate readings and is not affected by resistance changes in the thermo-couple circuit. The meter or indicating instrument of a pyrometer, either of the millivoltmeter or potentiometer types, may either be arranged to show the temperature at any time by a graduated scale and pointer, or may be designed to trace a record of temperature changes upon a chart.

Poundal. The expression "poundal" is sometimes used in connection with calculations in mechanics. Many mechanical handbooks, however, do not define it, because of its limited use. A poundal is a unit of force, and is defined as that force which, acting on a mass of one pound for one second, produces a velocity of one foot per second. A foot-poundal is a unit of energy equal to the energy resulting when a force of one poundal acts through a distance of one foot. In order to reduce foot-poundals to foot-pounds, multiply the number of foot-poundals by 0.03108. Dividing the number of foot-poundals by 32.16 (acceleration due to gravity) will also give foot-pounds.

Pound-Foot. Torque or turning moment, should be expressed as pound-feet or pound-inches, instead of using the term foot-pounds or inch-pounds. Since the foot-pound is the unit of work

and is used in horsepower calculations, it is considered preferable to reverse it and use the term pound-foot to indicate torque or turning moment. The reversal of these terms serves to distinguish readily the two units of measurement—the unit of work and the unit of turning moment. The latter ordinarily is expressed as pound-inches instead of pound-feet, because the dimensions of shafts and other machine parts ordinarily are given in inches.

Pounds per Square Inch. The pressure of steam, air, water or any gases or fluids is given ordinarily in relation to the square inch. 1 pound per square inch = 144 pounds per square foot = 0.0703 kilogram per square centimeter = 2.31 feet of water at 62° F. = 27.7 inches of water at 62° F. = 2.042 inches of mercury at 62° F. = 0.068 atmosphere.

Powder Metallurgy. Powder metallurgy may be defined as the use of metal powders, with or without bonding agents, to produce articles by the application of pressure and heat. The method may be applied to single metals or to mixtures of two or more to form a sintered alloy; further, it is possible to incorporate non-metallic powders if so desired. The pressing operation may be carried out hot or cold. The sintering temperature is usually well below the melting point of the metal or metals concerned. The final product of powder metallurgy may be closely similar to that produced by the ordinary methods of casting and fabrication or it may have special features or properties unattainable by ordinary methods.

General Methods: There are two general methods of powder metallurgy in use. These are: (a) Pressing of the powder at room temperature, followed by sintering in a suitable atmosphere at a temperature which is, in general, about two-thirds of the melting point of the alloy. (b) Pressing of the powder at such a high temperature that sintering takes place at the same time as the pressing. The first is the more common method, since with the second, high pressures may have to be applied to hot metal powders in a controlled, non-oxidizing atmosphere, and this involves complicated equipment.

Control of Composition: By the use of metal powders, alloy compositions can be accurately controlled and bronzes and gun metals, for example, can be produced with an accuracy and uniformity unattainable by foundry methods. Segregation and its accompanying evils are entirely eliminated. Bi-metals such as nickel-iron and tungsten-copper can be produced in bars, the layers of which are perfectly welded together; the latter combination could hardly be produced at all by ordinary methods. Alloys having constituents that are widely different in melting point (and, therefore, cause difficulty in the foundry), can easily

be produced by powder metallurgy. In this class, the lead-copper alloy which has such desirable bearing properties is important.

Special Mixtures: The possibility of introducing non-metallic powders permits of producing materials with special characteristics, as for example, the copper and graphite mixture used for generator and motor brushes, and the well-known oilless bearings, in which graphite is used in addition to copper and tin powders.

Materials Having High Melting Points: Materials having a high melting point, such as tungsten, molybdenum, and tantalum are so refractory to ordinary processes that powder metallurgy is practically the only method by which they can be made commercially available, and makes possible the incorporation of the thoria which gives the wire its "non-sag" characteristics when used for filaments.

The various forms of hard-cutting materials of the cemented-carbide type, owing to their high melting points and the necessity of providing a plastic bond, can also be produced most advantageously by the powder method.

Controlled Porosity: It is possible by the control of particle size, pressure, type of bond, and sintering temperature to produce material of controlled porosity. This may, for some applications, be highly desirable, as in the case of oilless bearings, where the pores act as oil capillaries, or as minute oil reservoirs.

Highly porous articles can be made successfully by bonding the powder with some foam-producing agent, which is destroyed by the heat of sintering, leaving a metallic "foam" behind; such material may be useful for filters, storage battery plates, and other purposes

Accurate Dimensions: The dimensions of sintered articles can be held to close tolerances, since the dies for forming the powder compress can be accurately made, and by careful control, the volume changes on sintering can be closely regulated. These already close dimensions can be further improved by repressing and coining, so that the finished article is extremely accurate. Although the first cost of the metallic powder is generally high, there is practically no loss of material during the manufacturing cycle, since the powder is accurately controlled by hopper feeds.

Power. Power, in mechanics, is *the product of force by distance divided by time*, or the performance of a given amount of work in a given time. Power is measured in inch-pounds per minute or second, foot-pounds per minute or second, etc. The term *power* is frequently used by writers on mechanics to designate a *force*. In connection with the so-called *mechanical powers*

—the lever, wheel and axle, wedge, screw, etc.—the applied force is frequently spoken of as the power. This is, however, not strictly correct, as power should always, in mechanics, be used in accordance with the definition given. *Horsepower* is the unit of power adopted for engineering work, and equals 33,000 foot-pounds per minute. See Horsepower.

Power and Heat Equivalents. In some engineering calculations, it is necessary to convert standard units into units of another kind. For example, horsepower units may be changed into electrical units, or into heat units, etc. The following power and heat equivalents include the units in general use.

One horsepower-hour = 0.746 kilowatt-hour = 1,980,000 foot-pounds = 2545 B.T.U. (British thermal units) = 2.64 pounds of water evaporated at 212° F. = 17 pounds of water raised from 62° to 212° F.

One kilowatt-hour = 1000 watt-hours = 1.34 horsepower-hour = 2,655,200 foot-pounds = 3,600,000 joules = 3415 B.T.U. = 3.54 pounds of water evaporated at 212° F. = 22.8 pounds of water raised from 62° to 212° F.

One horsepower = 746 watts = 0.746 kilowatt = 33,000 foot-pounds per minute = 550 foot-pounds per second = 2545 B.T.U. per hour=42.4 B.T.U. per minute=0.71 B.T.U. per second=2.64 pounds of water evaporated per hour at 212° F.

One kilowatt = 1000 watts = 1.34 horsepower = 2,655,200 foot-pounds per hour = 44,200 foot-pounds per minute = 737 foot-pounds per second = 3415 B.T.U. per hour = 57 B.T.U. per minute = 0.95 B.T.U. per second = 3.54 pounds of water evaporated per hour at 212° F.

One watt = 1 joule per second = 0.00134 horsepower = 0.001 kilowatt = 3.42 B.T.U. per hour = 44.22 foot-pounds per minute = 0.74 foot-pounds per second = 0.0035 pound of water evaporated per hour at 212° F.

One B.T.U. (British thermal unit) = 1052 watt-seconds = 778 foot-pounds = 0.252 kilogram-calorie = 0.000292 kilowatt-hour = 0.000393 horsepower-hour = 0.00104 pound of water evaporated at 212° F.

One foot-pound = 1.36 joule = 0.000000377 kilowatt-hour = 0.00129 B.T.U. = 0.0000005 horsepower-hour.

One joule = 1 watt-second = 0.000000278 kilowatt-hour = 0.00095 B.T.U. = 0.74 foot-pound.

Power Brush Finishing. Power brush finishing is a production method of metal finishing that employs wire, cord, fabric or Tampico brushing wheels in automatic, semi-automatic or conventional machines to smooth or roughen surfaces, remove surface encrustations or remove burrs.

The type of finish produced depends upon the wheel material and how the wheel is applied. The cord and fabric, Tampico and treated Tampico, and fine wire section wheels are used when a surface roughness of less than 30 microinches, AA, is required. The cord and fabric wheels have medium brush flexibility, very fine (low AA) brush finishing ability and medium brushing action as compared with the fine wire section wheels which have a high brush flexibility, a medium brush finishing ability and a very fast brushing action. The Tampico and treated Tampico wheels have characteristics that are approximately midway between the two. Other types of wire wheels are used when a surface roughness greater than 30 microinches, AA, is permitted or required. The brush flexibility, brush finishing ability and brushing action are low, fine, and medium fast, respectively, for the wire wheels and high, coarse, and fast, respectively, for the coiled knot wire section wheels. The characteristics of the plain wire section wheels lie approximately midway between the characteristics given for the wire and coiled knot wire section wheels.

The brushes should be located so as to bring the full face of the brush in contact with the work. Full face contact is necessary to avoid grooving the brush. Operations that are set up with the brush face not in full contact with the work require some provision for dressing the brush face. When the tips of a brush used with full face contact become dull during use, with subsequent loss of working clearance, reconditioning and resharpening is necessary. This is accomplished simply and efficiently by alternately reversing the direction of rotation during use.

Brushing speeds vary considerably from job to job depending upon the speed of the work or brushing intervals. While it is difficult to give specific speeds, the following, given in feet per minute, have been recommended for various general classifications: removing burrs, 5500 to 7500; blending for mechanical strength, 4700 to 7500; cleaning dry (wire brushes), 4000 to 5500; scrubbing wet, 1900 to 4000; finishing for appearance, polishing, 6400 to 8000; finishing for appearance, buffing, 8000 to 10,000; removing scale, 7500 to 10,000; and cleaning welds, 7200 to 9400.

Power Factor. In an alternating-current circuit, the electromotive force and the current may or may not be in phase, and the difference in phase determines the "power factor." The power factor is the ratio of the real power to the apparent power. This ratio is generally less than 1, and can never be greater. When the current leads the electromotive force, the power factor is not

greater than unity, but is distinguished from that caused by lagging current by calling it "leading" power factor.

Power Hammers. See Hammers, Forging.

Power of a Number. Power, in mathematics, indicates the number of times that a certain quantity is repeated as a factor. For example, the *third power* of 5 equals $5 \times 5 \times 5 = 125$. The *fifth power* of 2 equals $2 \times 2 \times 2 \times 2 \times 2 = 32$. The power is designated by an *exponent;* thus the third power of 5 is written "5^3," and the fifth power of 2 is written "2^5." The small figure in upper right-hand corner of expression is known as *exponent.*

Power Presses. In order to handle the wide range of work now done by means of dies, many different types of power presses are required. These presses, like the dies used in them, are difficult to classify because of the variety of designs and the different features which may properly be considered in making the classification. The names commonly given presses by manufacturers indicate, in some cases, the class of work for which the press is intended; whereas the names applied to other types are derived from the constructional features. As examples of names which indicate the nature of the work for which the press was designed, there are drawing, embossing, trimming, punching, forging, wiring, and perforating presses, etc. The construction of presses for these different classes of work varies considerably, there being single-action, double-action, triple-action, multiple-crank, cam, knuckle-joint, and toggle presses. As is apparent, these names are based on constructional features and indicate particularly the nature of the mechanism which operates the slide or ram of the press. Presses are still further classified according to the design of the frames, as indicated by the names inclinable, straight-sided, arch, gap, adjustable-bed presses, etc. In many cases, the names previously referred to are combined, whereas, in others, they are not. For instance, the names inclinable press, straight-sided press, arch press, double-crank press, etc., are commonly used and simply refer to constructional features, whereas combination names, such as toggle-drawing press, knuckle-joint embossing press, straight-sided trimming press, etc., suggest the general nature of the work for which the press is intended, as well as some important constructional feature. While power presses are made in an almost endless variety of designs, there are, however, certain types which might be considered standard, although different makes vary more or less in regard to constructional details. See Double-action Presses; Embossing and Coining Presses; Friction-driven Screw Press; Gang Presses; Inclinable Power Presses; Knuckle-joint Embossing Press; Multiple-crank Presses; Straight-sided Power Presses; Stagger-feed Press.

Power Press Feed Mechanisms. When mechanical feeds on power presses are warranted by a reasonably large production or by the character of the work, they effect economies by increasing the normal production rate or decreasing the labor cost, or by a combination of both. The type of press, the length of stroke, and the work to be handled all affect the speed of hand feeding. Obviously, strip stock which does not have to be accurately located can be fed very rapidly by hand, and on such work there might be little economy in equipping presses running at less than 30 to 40 strokes a minute with mechanical feeds. Work requiring to be located more accurately, however, or parts that are hard to place correctly in the die, may be fed mechanically to advantage, even at much lower speeds. The increase in production effected by mechanical feeding may be due to speeding up the press or to the fact that the feed "catches" every stroke with the press running continuously, while without a feed, the operator may have to trip each time or he may require that the press be run more slowly to feed every stroke.

Driving Mechanical Feeds: The matter of driving and timing mechanical feeds properly is a problem in selecting the most suitable driving method and so arranging it as to make the most of the available time in the cycle and to get the smoothest action. Smooth action, uniform acceleration and deceleration, and the design of parts so that the possibility of wear and backlash occurring is reduced to a minimum are essential in securing and maintaining accuracy and reliability. Most press-feeding involves one uniform motion, in the same direction, at each stroke of the press. In the majority of cases, this is derived from a crank or a cam on the free protruding end of the press crankshaft, although in some cases sprockets, gears, etc., are used in connection with clutches, grippers, or friction devices. In general, where there is a choice, a crank motion is decidedly preferable to a cam motion, because it can be run faster, is easier to adjust and maintain, and is much cheaper to construct.

Arc for Feed Motion: The working portion of the stroke on single-action crank presses is considered in most cases to be up to half (the lower half) of the down stroke or from 90 degrees to 180 degrees (nearly) as the shaft revolves. If all of this is used, then another full quarter turn will be required on the up stroke to bring the punch clear. This leaves a full half turn (180 degrees), from 270 to 90 degrees, for feeding. If a straight crank motion is used, it requires this remaining 180 degrees for the feed stroke. The feed is usually arranged on the up stroke of the crank-pin to bring the connecting-rods into tension while feeding. A simple crank-driven feed motion, with the feed crank-

pin 90 degrees in advance of the press crankpin, brings the feeding action on the up stroke and, provided the connecting-rod works vertically, the feed begins at 270 degrees and finishes at 90 degrees. This drive is suitable for dial or roll feeds and the like, provided the working portion of the stroke is completed and the punches are clear again in less than 180 degrees. This is necessary because the dial or strip material passes under the punches in feeding, and obviously, there must be no interference.

The crank-driven feed motion with the feed crankpin advanced 180 degrees ahead of the press crankpin, is suitable for some magazine feeds and special push feeds, where the first part of the feed stroke is to pick up a slug from a stack, and the last part (90 degrees or less) is to deliver it to the die, or where a portion of the feed mechanism must cross the die and return it in locating the work. For the first case, this timing has the advantage that the feed is completed before the stopping position of the press is reached—a favorable point when setting up and adjusting.

Double-action presses in general, and single-action presses in some cases, are not suited to the plain crank drive on account of not having a full half cycle (180 degrees) available for the feed action. This applies only, of course, to roll and dial feeds and the like, in which the work or the feed itself travels under the punches through the whole feeding stroke. Double-action toggle presses are usually stopped about 15 degrees ahead of top center, as this is the highest point reached simultaneously by both slides. The blank-holder dwell is arranged to start before the punch reaches the material, and to hold until about 10 degrees after the draw is completed. There remains about 135 degrees during which the work space is clear for feeding.

Power Press Indexing Feeds. Feeds designed to grip and advance or rotate strip, circular, cylindrical, or conical shaped work for a series of punching, notching, perforating, or stamping operations, equally spaced, usually require special treatment to suit the particular job. Specific applications include, for instance, feeds for use in perforating cylindrical or conical shapes, armature disk notching, silver-plate decorating, flat perforating, etc. The essential features common to most of these feeds are means of locating the work accurately; means of gripping it securely; feeding motion (usually a ratchet type, crankdriven); and a device to stop the press after the desired number of strokes. Also in most cases, there must be means of stopping the press at any time and, especially for flat work, a cam stripper to reduce distortion to a minimum. Convenience of arrangement and accuracy are essential to all feeds. Indexing feeds in general are not

adaptable to standardization, on account of the wide variation in the work to be handled and in the types of presses they are applied to. However, all have the same general characteristics of advancing and rotating the work a fixed amount for a predetermined number of strokes, and then stopping the press, and therefore make use of similar motions and devices.

Power Press Magazine Feeds. Magazine feeds, which in some cases are also called coin feeds and tube feeds, are a comparatively simple type, adapted to handling blanks of sufficient thickness to permit of being fed out positively from the bottom of a stack. They are also used in some cases for such stampings or forgings as can be stacked without danger of nesting or interlocking and are not so high as to be in danger of toppling over. This type of feed can usually be built as an entirely self-contained unit, which may be bolted to the press bolster. It may be placed either at the front or the side of the press, and can be applied to practically any type of press. Placing the feed at the side is usually the most satisfactory for end-wheel type gap-frame presses, on account of the drive, but for the side-wheel type presses, it may be mounted either at the front or the side, according to the conditions of the individual case. Adjustment can be provided on the driving crankpin to alter the length of the feed stroke, but as this is rarely necessary, a fixed crankpin is more usual.

Magazine feeds for press work are used particularly in connection with coining, swaging, piercing, and forming operations, and on some stamping and repunching work. These feeds are sometimes used in connection with hopper feeds, which are rather complicated. Another modification includes the use of gripper fingers on the reciprocating slide, in which case the blank is dropped into the die centrally, instead of being pushed into it. It is often possible, when magazine feeds are being used, to utilize some sort of stacking device under the press, to receive the blanks and facilitate feeding.

Gravity Chute Feeds: Gravity chute feeds are comparatively simple, consisting only of a chute of proper dimensions, down which the work moves by gravity, and a releasing device to drop one piece at a time into the die, with sometimes the addition of a mechanism to gage and hold the shell in the proper position. The presses are usually used either in the horizontal position on special legs or inclined back 45 degrees or more from the vertical. This method of feeding is limited to parts that can be put into a chute without danger of becoming twisted or of overlapping. Gravity chute feeds are also used on automatic machines for rolling beads and threads, or similar work.

Hopper Feeds: On some classes of work, where small partially worked symmetrical parts are fed in large quantities to fast presses, hopper feeds are advisable. They include a hopper, or receiver, in which the pieces are agitated, and those that fall in the right position are passed on, timed, and carried by some one of the simpler feed motions into the die. Hopper feeds for screw blanks or parts that can be picked up by the head, are more or less standardized, and are quite well known. Hopper feeds for press work, however, present a more serious problem, on account of irregularities in the parts and the dangers of injury, jamming, and misfeeding. The development cost is necessarily high, as each feed presents a problem in itself, and frequently requires some novel solution.

Power Press Ratchet Dial Feeds. Ratchet or station dial feeds consist essentially of a dial having stations to hold the work being operated on, and driven from the press shaft by a suitable ratchet mechanism, so that the stations are brought successively, accurately and positively under the punch. The drive may be from the simple crank disk on the end of the shaft, although in some cases, it is necessary to use a cam drive or scotch-yoke drive where less than 180 degrees is available for feeding. The dials are of two general classes—those having a locating bushing in each station on the dial to carry the work into alignment over a die in the bolster below the dial; and those having a complete die at each station on the dial.

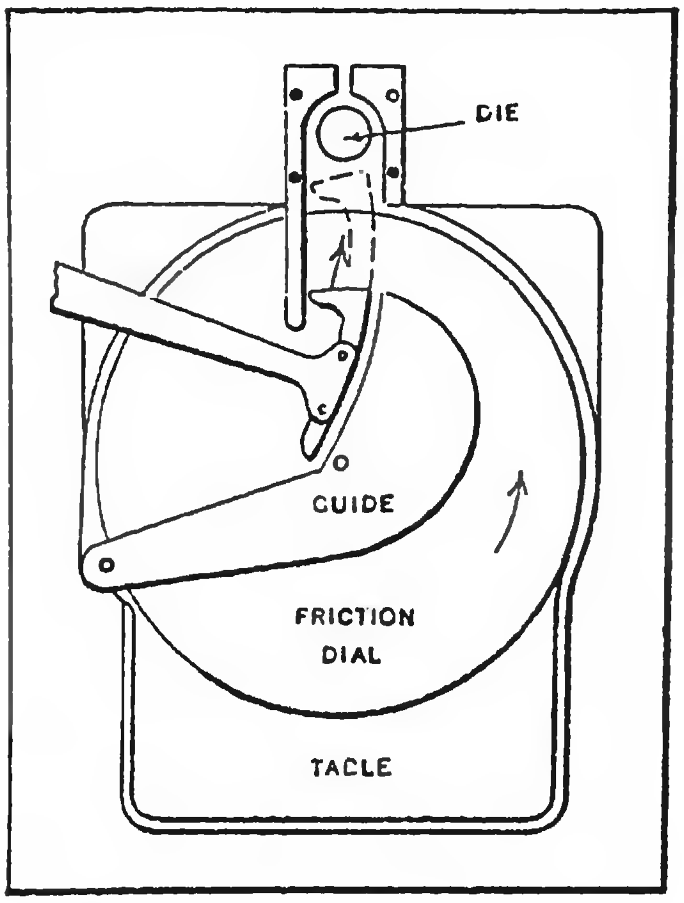
Obviously, the structural requirements of this type of feed are that the dial shall move smoothly and accurately, that the notches and stations shall all be very accurately located and machined so that the work will be properly aligned with the punch every time, that the feed motion shall function accurately and reliably, and that lost motion and the opportunity for wear shall be reduced to a minimum. Dial bushings or dies must be interchangeable. The class of machine work required on a dial feed is very high.

These station dial feeds are adapted especially to handling work for secondary operations, such as redrawing, piercing, stamping, broaching, wiring, punching, and burring. Sometimes it is possible to perform two or three operations in sequence at successive stations. In such cases, it is advisable to balance the operation so that the strain on the slide will not be much off center, and to provide separate adjustments for height on the punches. Feeds of this type are also used for assembling, riveting, and closing operations on finished parts and on material other than metal.

As these feeds are ordinarily arranged, the operator places the work in the bushings or on the posts at the front of the dial,

from which point they are carried around into the working position and then ejected. An unskilled operator can catch every stroke of a press that is operating at full speed, and can accomplish this without any danger of losing a hand.

Friction Dial Feeds: The accompanying illustration represents diagrammatically a plan of a typical friction dial feed. This is a comparatively simple type of feed consisting, as a rule, of a table, a revolving friction disk on which are suitable guides, and a lateral feed or escapement. The operator has only to push the shells from the table to the disk, right side up. The combination of the friction drive and the guides lines them up and the escapement feeds the pieces one at a time into the die or series of dies. This type of feeding mechanism is suited especially to handling parts (usually drawn shells) that have their center of gravity low enough so that they are not likely to tip over. The exact design varies more or less.



Plan of Typical Friction Dial Feed

Power Press Roll Feeds. Roll feeds, suited to feeding strip or ribbon stock by means of intermittently driven rolls, are quite universal in their range of work, when properly designed, and are readily adaptable to standardization, when they are built in sufficient quantity. The whole feed can be built as a self-contained unit on a bolster plate, with merely a driving collar or arm for the end of the shaft. Roll feeds may be arranged to operate either front and back or right and left (the most common method) on gap-frame presses, and front and back on straight-sided presses or right and left on such presses when arrangement can be made to feed through an opening in the housing.

Single roll feeds are those having only one pair of rolls at one end of the bolster, adapted either to pushing across the die, stock that is sufficiently stiff to preclude the chance of buckling, or to pulling the strip across by the scrap, where the scrap is strong enough not to break and is not too deformed. Double-roll feeds are built with a pair of rolls at each end of the bolster, so that the pulling stress on the stock is somewhat distributed and the material between the rolls is kept taut, preventing wrinkling or

buckling; they are therefore suited especially to very thin or narrow material or to material lacking stiffness and body, though they are often used with heavier materials for control at start and end. Double-roll feeds are very similar to the single-roll type, requiring merely the addition of a practically identical housing and pair of rolls. For short feeds, the second pair of rolls is provided with another friction device, which is driven from the first pair by the reciprocating motion of a connecting cross-bar. When the feed exceeds 90 or 100 degrees on the rolls, bevel gears and a connecting-shaft are used.

The length of the feed is governed by the diameter of the rolls and by the arrangement. The direct-connected feed is limited to a maximum feeding arc of about 100 degrees. Longer feed strokes are obtained by the use of a rack connected with the crank block and driving a gear having the friction grip device built into it. For an accurate feed, especially of the friction type, there should be the least possible opportunity for backlash between the friction device or ratchet and the rolls.

There are various accessory attachments used occasionally with roll feeds to suit special conditions. These include strip oiling and straightening devices and scrap-cutting shears or scrap-winding reels. Scrap-winding devices coil up the scrap material so as to make subsequent handling easy. Another method with a similar object is to provide a small gate shear driven from the slide or shaft of the press to cut off a portion of the scrap at each stroke, so that it falls into a barrel or tote box and no rehandling is necessary.

Power Press Safeguards. To prevent power-press accidents, the hands of the operator should be kept from under the ram when it descends, by means of mechanical safeguards put on the machines for this purpose. Four methods by which this can be done are as follows: 1. By having a guard which pushes the hand away before the ram descends. 2. By having a device which prevents the clutch being thrown, locking the ram in its upper position while the operator's hands are under the ram, but releasing it when the hands are removed. 3. By having a guard entirely surrounding the danger zone. 4. By requiring both hands to be used to operate the machine. The machines which are operated by the foot will require guards of the first, second, or third classes, as the hands will be free to get in the way of the descending ram. A machine so designed as to require the use of both hands to operate it is a safety device in itself; but if only one hand is required, then it would be advisable to adopt one of the other three methods. A guard should not hinder the workman,

and it should be so attached to the machine that it cannot readily be removed and discarded.

Power Press Selection. In selecting a press, there are a number of factors to be considered. These include type of frame, power, speed, and stroke. Gap (or cut-back) frame presses lend themselves most readily to the application of feeds, and the inclinable feature on some types is of value to effect gravity discharge from the die. Arch-frame and straight-sided frame presses are not so convenient for the arrangement of all types of feeds, but have the advantage of straight-frame spring only, or still less spring in the case of a built-up frame presses properly assembled.

Gap-frame presses will spring on an arc about in proportion to the load. The effect of this spring in presses that have not been selected with sufficient care is to cause a less distinct impression at the front in stamping work, and a tendency to wear, especially at the front and back in blanking dies—particularly in those in which there is very little clearance between the punch and die. It was demonstrated in one case, for instance, that the life of expensive dies was increased from about 15,000 punchings per grind to 250,000 by changing to a heavier and stiffer press, although the original press appeared to be handling the work with ease.

The required strength of the press frame and shaft depends upon the load or pressure to be exerted. The power requirement governing flywheel, gearing, and motor depends upon the stroke and work; that is, the energy to be delivered is the product of the pressure and the distance through which it must act. Thus for short-stroke blanking work, a flywheel press is usually sufficient, but for long-stroke drawing or forming work requiring the same pressure but exerted through a longer distance, a geared press is necessary, as its flywheel runs proportionately much faster and makes available more energy for the same percentage of speed reduction.

During the short portion of the stroke in which the actual work is done, the motor is called on to stand an instantaneous overload of 50 to 75 per cent and a speed reduction of 10 to 20 per cent. It is the flywheel and not the motor, however, which supplies the bulk of the energy to perform the work, and the chief function of the motor is to restore the lost energy (and speed) to the flywheel during the idle time between working periods. It is evident that a press may have sufficient power to "pull" a given job when the press is tripped each stroke and the recuperating period between strokes is long; but when the same press on the same job is fitted with a mechanical feed catching every stroke, the power

demand comes oftener, and the recuperating period is shorter, so that more power is demanded of the motor, and a larger motor may be required.

Power Press Stop Mechanism. See "Beaver-tail" Stop.

Power Press Tonnage. The method of rating power presses varies considerably among different manufacturers. Some rate their presses by number, the number used bearing a certain relation to the diameter of the crankpin or crankshaft. For instance, the number may be determined by some "rule of thumb" as, for example, by using the square of the crankshaft diameter as a basis. The number given to a press, however, does not always indicate its capacity, which may depend, to a certain extent, upon the gearing. Other manufacturers use the diameter of the flywheel and its maximum velocity as a basis upon which to rate the capacity of the press. Another method is to calculate the diameter of the crankpin in practically the same manner as a beam supported at both ends, the cross-section of the crankpin being determined by what the tonnage would be at the dead point. In other words, the dead-point tonnage is used to indicate the tonnage of the press. By this method, however, the tonnage has no direct relation to the number given, which is chosen arbitrarily. According to another method, the nominal capacity of the press in tons is equal to three and one-half times the square of the diameter of the crankshaft. For instance, a press having a 2-inch-diameter crankshaft would have a nominal rating of 14 tons. The nominal tonnage of a press may also be related to the strength of the frame and crankshaft, and establishes a standard stroke, any increase in the stroke changing the capacity of the press.

The following empirical rules, for computing the tonnage by the weight of the press, depend for their usefulness on the presses to which they are applied; hence, these rules are not intended for general application but are given as examples. According to one rule, the weight in pounds of a straight-side or pillar press divided by 80 will give the capacity of the press in tons. On overhanging presses of ordinary design the weight of the press should be divided by 100 to 120 to obtain the tonnage. For example, the tonnage of a straight-side press weighing 5600 pounds is $5600 \div 80 = 70$ tons, which is approximately correct. In the case of an overhanging press weighing, say, 3200 pounds, with an average depth of throat of about 7 inches, we have $3200 \div 100 = 32$ tons capacity, which also is close to the correct figure. On small overhanging presses the weight of the flywheel divided by 16 gives the tonnage of the press closely, but on large presses weighing 2500 pounds or more, the weight of

the flywheel is divided by 20 in order to get the approximate tonnage.

Power Spinning. See Spinning Metals.

Pozzuolanic Cement. Pozzuolanic (or Puzzolan) cement, also known as *slag cement*, is a finely pulverized product obtained by making a mechanical mixture of granulated basic blast furnace slag and hydrated lime, this mixture being ground to obtain the cement. The blast furnace slag is granulated by being run into water while in a fused condition. The usual proportions in the mixture are three parts of slag to one part of slaked lime, by weight. Slag cement is not as strong, uniform, or as reliable as Portland or natural cements, and should be used only for foundation work under ground, where it is not exposed to air or running water. It sets slowly, but its strength increases considerably with age. Although it is a cheap material, suitable for many purposes, it is not largely used.

Precipitation. In chemistry, precipitation is the process of separating a substance from a solution by adding another substance to the solution. The separated substance is known as the *precipitate*, and the substance which is added to cause the precipitation is known as the *precipitant*.

Precipitation Hardening. When hardening is caused by the precipitation of a constituent of a supersaturated solid solution, this hardening is known as precipitation hardening. See also Aging.

Precision Lathe. See Lathe Classification.

Preferred Numbers. Preferred numbers are series of numbers selected to be used for standardization purposes in preference to any other numbers. Their use will lead to simplified practice and they should, therefore, be employed whenever possible for individual standard sizes and ratings, or for a series thereof, in applications similar to the following:

1. Important or characteristic linear dimensions, such as diameters and lengths, areas, volume, weights, capacities.
2. Ratings of machinery and apparatus in horsepower, kilowatts, kilovolt-amperes, voltages, currents, speeds, power-factors, pressures, heat units, temperatures, gas or liquid-flow units, weight-handling capacities, etc.
3. Characteristic ratios of figures for all kinds of units.

Preferred Numbers System: In order to facilitate the standardization of a series of sizes or ratings along logical and rational lines, preferred numbers have been selected to have definite rela-

tions to one another. The proposed International System, which has been approved by the American Standards Association, covers the so-called "5-, 10-, 20- and 40-series," and in the range from 10 to 100, the numbers are as follows:

5-series: This series gives 5 numbers approximately 60 per cent apart. These are 10, 16, 25, 40, and 63.

10-series: This series gives 10 numbers approximately 25 per cent apart. These are 10, 12.5, 16, 20, 25, 31.5, 40, 50, 63, and 80.

20-series: This series gives 20 numbers approximately 12 per cent apart. These are 10, 11.2, 12.5, 14, 16, 18, 20, 22.4, 25, 28, 31.5, 35.5, 40, 45, 50, 56, 63, 71, 80, and 90.

40-series: This series gives 40 numbers approximately 6 per cent apart. These are 10, 10.6, 11.2, 11.8, 12.5, 13.2, 14, 15, 16, 17, 18, 19, 20, 21.2, 22.4, 23.6, 25, 26.5, 28, 30, 31.5, 33.5, 35.5, 37.5, 40, 42.5, 45, 47.5, 50, 53, 56, 60, 63, 67, 71, 75, 80, 85, 90, and 95.

Preferred numbers above 100 are obtained by multiplying the given numbers by 10, 100, etc. Numbers below 10 are obtained by dividing the given numbers by 10, 100, etc.

The American Standard includes a fractional system of preferred numbers over a limited range. It is based on the same general principle and may be used for linear dimensions in inches, where fractions are in such common use that decimals could not be applied readily. There is also an 80-series having 3 per cent steps and a supplementary series.

Theoretical Basis for the Preferred Numbers System: Preferred numbers are based on geometrical series. Using 10 as the first number of the series, the other theoretically exact numbers of any series are obtained by multiplying (or dividing) the first number by the constant factor applying to the particular series and repeating this operation with each resultant number. These factors are established as follows:

For the 5 series, the factor is the fifth root of 10, or 1.5849.

For the 10 series, the factor is the tenth root of 10, or 1.2589.

For the 20 series, the factor is the twentieth root of 10, or 1.1220.

For the 40 series, the factor is the fortieth root of 10, or 1.0593.

The formation of the various series may also be accomplished by starting with the 40-series and taking every other number to form the 20-series; every fourth number for the 10-series, and every eighth number for the 5-series. The standard numbers are approximations of the theoretical values, the departure from these theoretical values being in no case more than 1.3 per cent.

Preloaded Bearings. Preloaded bearings are anti-friction bearings that have been assembled under stress conditions so that application of the load to the bearing would cause little or no deflection.

Premium Wage System. There is some similarity between the premium wage-paying system and the *differential wage system.* The difference between the two systems is that, in the premium plan, the increased pay is based upon the *time saved* instead of upon an increase in the piece rate. The standard of efficiency is fixed by determining upon a reasonable time in which the work can be completed. If the workman completes the work in a shorter time, he receives his regular hourly rate for the time that he has worked upon the job, and, in addition, he receives a premium for having worked faster than the standard requirements, this premium consisting of from 25 to 50 per cent of the difference between the wages earned in the shorter time and the wages that would have been paid if the job had been done in the fixed standard time. A minimum wage is generally incorporated in this system, so that the workman is always insured of a certain amount of pay in case he is not able to earn a premium. See Wage System, Premium.

Prescoloy. A nickel-alloy steel of high strength, especially developed for use in the railway field. Used for cast nickel-steel railway trucks that weigh 13,000 pounds less than previous designs, but carry 26,000 pounds more load.

Present Value. In the appraisal of manufacturing plants, the value of equipment at the time of the appraisal is known as the "present value." It equals the *replacement value* less the accrued *depreciation* at the time of the appraisal.

Press Brake. See Brakes for Bending.

Pressed Fits. See Forced Fits.

Pressed Steel. The term "pressed steel" is commonly applied to parts made from sheet steel by the die and press method. Pressed-steel parts have been used in many lines of manufacture to replace castings, forgings, and machined parts. The advantages of using pressed-steel parts often include such factors as reduction in weight and accompanying reduction in cost of raw materials and transportation charges for finished products; increased strength, as compared with replaced parts; larger production; and improved appearance of finished parts.

Presses. See Drop Presses; Hydraulic Presses; Power Presses.

Pressure, Absolute and Gage. See Absolute and Gage Pressure.

Pressure Angle of Gearing. A line drawn tangent to the two base circles of intermeshing spur gears is known as the *line of action,* because the point of contact between two gear teeth having involute curvature is along this line as the teeth roll in mesh with each other. This line of action may be represented by a crossed belt, if the base circles are considered as pulleys connected by such a belt. The angle between this line of action and a line perpendicular to the center line of the two gears, is known as the *pressure angle* of the gearing. Gearing is commonly designated by giving the pressure angle. For instance, the expression 14½ degrees, 20 degrees, etc., as applied to gearing, relates to the pressure angle of the gearing.

In the design and manufacture of gearing, certain pitches, pressure angles and tooth proportions have been used so extensively that they are generally accepted as standards. While 14½ degrees is the most common pressure angle, as applied to miscellaneous classes of gearing, 20 degrees may be regarded as the standard sanctioned by common usage for certain types of transmission gears, and herringbone gears usually have an angle of 23 degrees. Bevel gears, as well as spur gears, are designed for both 14½- and 20-degree pressure angles, and other angles are employed. A 14½-degree angle is unsatisfactory for exceptionally small gears (especially if the teeth are of standard or ordinary proportions) because of under-cutting which weakens the teeth and causes poor tooth action when two gears revolve together. For information concerning the reasons why 14½ degrees was selected as a pressure angle, see Gear Teeth, Historical Notes.

Normal Pressure Angle: This term is applied to helical gearing to indicate the pressure angle in a plane normal or perpendicular to the teeth and distinguished from a plane that is perpendicular to the axis of the gear. The normal pressure angle is sometimes known as the *transverse pressure angle.*

To find the tangent of the pressure angle in the plane of rotation, divide the tangent of the normal pressure angle by the cosine of the helix angle. The tangent of the pressure angle in the plane of rotation also equals the tangent of the normal pressure angle multiplied by the secant of the helix angle.

To find the tangent of the normal pressure angle, multiply the tangent of the pressure angle in the plane of rotation by the cosine of the helix angle.

Pressure, Atmospheric. See Atmospheric Pressure.

Pressure Attachments for Drawing Dies. In the application of drawing dies for drawing hollow parts of various shapes, it is essential to apply enough pressure on the outer surface of the flange or flat blank to prevent the formation of wrinkles. Excessive pressure, however, will unduly strain the material and may result in fracturing it. There are several commercial types of pressure attachments designed to maintain a uniform blank-holder pressure or prevent an increase of pressure as the depth of the "draw" increases. Some of these attachments are equipped with combinations of springs and links and others have pneumatic cushions, the latter often being called die cushions. These modern types of pressure attachments not only improve the drawing operation but reduce the number of operations in many cases and, in addition, they increase the range of work which can be done on single-action presses.

Pressure Equivalents. 1 pound per square inch = 144 pounds per square foot = 0.068 atmosphere = 2.042 inches of mercury at 62 degrees F. = 27.7 inches of water at 62 degrees F. = 2.31 feet of water at 62 degrees F.; 1 atmosphere = 30 inches of mercury at 62 degrees F. = 14.7 pounds per square inch = 2116.3 pounds per square foot = 33.95 feet of water at 62 degrees F.; 1 foot of water at 62 degrees F. = 62.355 pounds per square foot = 0.433 pound per square inch; 1 inch of mercury at 62 degrees F. = 1.132 feet of water = 13.58 inches of water = 0.491 pound per square inch.

Pressure Fan. A special form of ordinary ventilating fan. See Fan Blower.

Pressure Head. The pressure against which a pump forces the water is usually expressed in "feet head." For example, a pump feeding a boiler against a pressure of 100 pounds per square inch is operating under a head of $100 \div 0.433 = 231$ feet; that is, each pound pressure per square inch against which the water is forced is equivalent to lifting a column of water 1 inch square and 2.31 feet high. From the above, it is evident that: Pressure per square inch in pounds $\div$ 0.433 = head in feet; head in feet $\times$ 0.433 = pressure per square inch in pounds.

In determining the pressure head or total height to which the water must be raised, the distance must be taken from the surface of the water in the reservoir from which it is drawn to the point of discharge. The same power is required to raise water by suction as to force it, and the height of the pump above the water does not enter separately into the calculation at all, provided the "lift" is within the maximum limit.

Pressure Regulator. In air compressors, a pressure regulator

is a device which closes the inlet pipe of an air compressor and connects the two ends of the air cylinder, when the receiver pressure reaches the maximum point desired.

Pricker. Prickers are small projections provided on the outside of a core barrel which serves to hold the green sand or loam when making a large core. Cast core barrels over eight inches in diameter are generally provided with cast prickers placed from 2 to 3 inches apart. Wooden core barrels are provided with nails driven closely all over the exterior surface, serving the same purpose as the cast projections.

Primary and Secondary. The terms "primary" and "secondary" as commonly used in electrical work, serve to distinguish the windings in regard to energy flow, the primary being that which receives the energy from the supply circuit, and the secondary that which receives the energy by induction from the primary.

Primary Cell. A primary cell is any apparatus for transforming chemical energy into electrical energy. A primary cell is frequently termed a primary battery, but the term primary battery properly used refers to the joining of two or more primary cells, which then form a battery. A primary cell generally consists of a liquid known as the electrolyte and two metals called the elements or electrodes. In dry cells, the liquid is replaced by some absorbent material saturated by the electrolyte.

Prime Mover. A prime mover may be defined as any machine which, by utilizing some of the forces of nature, produces power for the use of other machinery and devices. The principal prime movers are the steam engine and turbine, the gas and oil engine, the water turbine, and the windmill. The electric motor is not, strictly speaking, a prime mover, as it is driven by current obtained from a generator which, in turn, is driven by a prime mover. A prime mover may be defined briefly as a machine in which a natural form of energy is transformed into mechanical energy. The power from the prime mover is transmitted to the machine in which it is used for producing a given work, by some form of power transmission, which may either be mechanical, hydraulic, pneumatic, or electrical.

Prime Numbers. A prime number is one which is not exactly divisible by any number except itself and 1. Thus, 3, 5, 7, 11, 13, etc., are prime numbers. A factor which is a prime number is called a *prime factor*. Prime numbers play an important part in calculations relating to indexing, gearing ratios, etc. Tables of prime numbers will be found in mechanical engineering handbooks.

Priming. If the steam which is generated in a boiler contains an excessive amount of moisture as it passes into the steam main, this condition is commonly referred to as *priming*. This may be caused by impure water, too high a water-line, the presence of oil, or of certain alkalies used in the removal of scale. Priming may also be caused by forcing the boiler beyond the capacity for which it is designed. When the steam rises from the surface of the water with too high a velocity, it has a tendency to carry more or less spray with it, which, when once in suspension, does not readily settle against a rising current, and thus passes over into the main with the steam.

Principle of Archimedes. See Buoyancy.

Prism. A prism is a solid body in which the two end faces are parallel and in which the lines along which all the other faces intersect or meet are parallel. If all the sides of a prism are rectangles and the end faces are either squares or rectangles, the prism is called a *square prism*. In a square prism, the opposite surfaces or faces are parallel and all the angles are right angles.

Prismatic Borax. This is the common form of borax. It is not as suitable for use as a flux in soldering or welding as is jeweler's or octahedral borax, as it does not fuse as readily. See Borax.

Prismlac. A lacquer for obtaining unusual finishes, used either clear on polished metal surfaces or in combination with colors or bronze powders. The unusual finish is obtained by spraying the surface with a coat of colored lacquer enamel, followed by a coat of Prismlac, which becomes ornamented with crystals, when drying, that will cover the entire surface.

Proferall. Molybdenum-nickel-chromium alloy iron that can be made with a minimum tensile strength of 50,000 pounds per square inch; other grades vary from 60,000 to 80,000 pounds per square inch. Has superior wearing qualities. Used for cast camshafts and crankshafts for automobiles.

Profile Grinding Machine. The profile grinding machine is a special type of grinder designed to grind formed turning tools of irregular shape, such as are used for relieving formed milling cutters, etc. In the operation of one design, a master form is attached to one table and the piece to be ground is clamped in a fixed position to another table. The grinding wheel is made to reproduce the outline of the master form by means of a follower pin which is kept in contact with the master form. The radius

of the wheel is made to correspond with that of the follower pin by means of a diamond truing device.

Profile Paper. The horizontal ruling on profile paper is usually ten lines to the inch, and the vertical ruling is 20, 25, or 30 lines to the inch. Profile paper is used by civil engineers for representing the profile or cross-section of grades, cuts, embankments, excavations, etc. For the use of railway surveyors, the profile paper is made in continuous strips, folded between covers in book form; these books are called *profile books.* Standard profile paper is obtainable in green and orange ruling, and either in sheets or in rolls. The sizes of the sheets are 15 by 42 inches and the rolls contain 50 yards, 10 or 20 inches wide.

Profiling Machines. A profiling machine or "profiler" is a type of vertical milling machine which is largely used for making parts of guns, pistols, typewriters, sewing machines, and for similar work. Profiling machines are adapted to milling duplicate pieces having an irregular contour, especially in connection with interchangeable manufacture. The distinguishing feature of this type of machine is that the spindle and milling cutter, instead of revolving in a fixed position, are guided by a special former plate, the outline of which exactly corresponds to the shape required on the work. Most of the profilers used at the present time are hand-operated, so far as the feeding movements are concerned. They usually have either one or two cutter spindles, the two-spindle type being commonly used. Each spindle has a former pin which is located a fixed distance from the cutter and is guided around the former plate or model by feeding the cutter-slide and pin laterally and the work-table in a longitudinal direction. By this method, duplicate parts of irregular shape can be produced.

Semi-automatic Profiler: In armories, etc., where large numbers of irregular-shaped parts must be milled, semi-automatic profiling machines are used to some extent in place of the hand-operated type. The head in which the two cutter spindles are mounted is stationary while the machine is operating, and the required form or contour is obtained by the movement of the table. The latter is carried at the front end of a swinging arm which is journaled in the bed between the uprights, and as the table rotates, it is given an oscillating movement by means of a cam which is attached to it and bears against a stationary roller. This cam, which is located at the base of the work-table, must be made to suit the profile of the parts to be milled. The number of pieces that can be milled at one time depends upon their size and the length of the profile which requires machining. The parts to be milled are held in a special fixture attached to the top of the table, and the cutter passes from one part to the other as the

table revolves and is guided by the cam. When the cutter is traversing the spaces between the work, the table speed is automatically accelerated.

Profilometer. In measuring surface roughness with this instrument, the surface irregularities are measured and averaged as a diamond tracer point moves slowly across the surface, and a meter shows by direct reading the average deviation in microinches. The profilometer may be applied to flat, cylindrical or curved surfaces. Different types of tracers are obtainable to permit checking various surfaces, such as small holes and narrow slots.

Progression. In mathematics, a progression is a series of numbers which increases or decreases according to some definite law. Arithmetical progression is a series where each term is obtained by adding or subtracting a given quantity to or from the next preceding term. In geometrical progression, each succeeding term is produced by multiplying the preceding term by a given factor.

Progressive Assembly. In their simplest form, conveyor systems merely represent a method of carrying parts to specified points, but in automotive and other large manufacturing plants, the conveyor may also serve many other purposes. Important among these is the so-called method of progressive assembly. By this method, a conveyor system travels at a specified speed and carries the work past men who are employed to mount successive parts on the product as it is carried past them by the conveyor. Where the progressive assembling method is employed, various parts to be assembled are delivered at the proper points along the assembling line. The proper conveyor speed is a matter that can only be determined by actual operation. This method of assembling was originated in the automobile industry, and the results obtained were so successful that it has since been adapted to meet the requirements of other lines of manufacturing.

Progressive Dies. See Follow Dies.

Progressive Plug Gage. The name "progressive" is applied to a plug gage which has the "go" and "not go" gaging sections combined in a single unit. The minimum allowable diameter is followed by the "not go" end. The American Standard progressive types of plug gages are for diameters from 0.240 to 2.510 inches.

Projection. Mechanical drawings are based on a method of drawing known as "orthographic projection." In order to illustrate simply this method of drawing, assume that some object is held in the hand on the same level as the eyes and is turned so

that the front side, top side, and end are each seen successively. These different views will then correspond practically to the different views of the same object as represented by a mechanical drawing made according to the orthographic projection method. Mechanical drawings composed of views representing different sides of a machine part, tool, or some other mechanical device, show the length, breadth, and thickness of various portions of the piece accurately, which is a great advantage in mechanical work, because the chief purpose of most mechanical drawings is to represent mechanical devices so clearly that they may readily be constructed. An important part of the draftsman's work is to place on the drawing all necessary dimensions expressed either in feet, inches, or fractional parts of an inch, depending upon the size of the work and the degree of accuracy required. Working drawings also give, ordinarily, the tolerances.

Principle of Orthographic Projection: The representation of a plain rectangular block by means of separate views showing the shape as seen from the front, top, and side, will illustrate the principle of projection better than a drawing of some complicated mechanical device. At *A* (see illustration) this block, which is shaded, is represented as being enclosed by a box formed of glass sides. If lines were extended or projected from the four corners

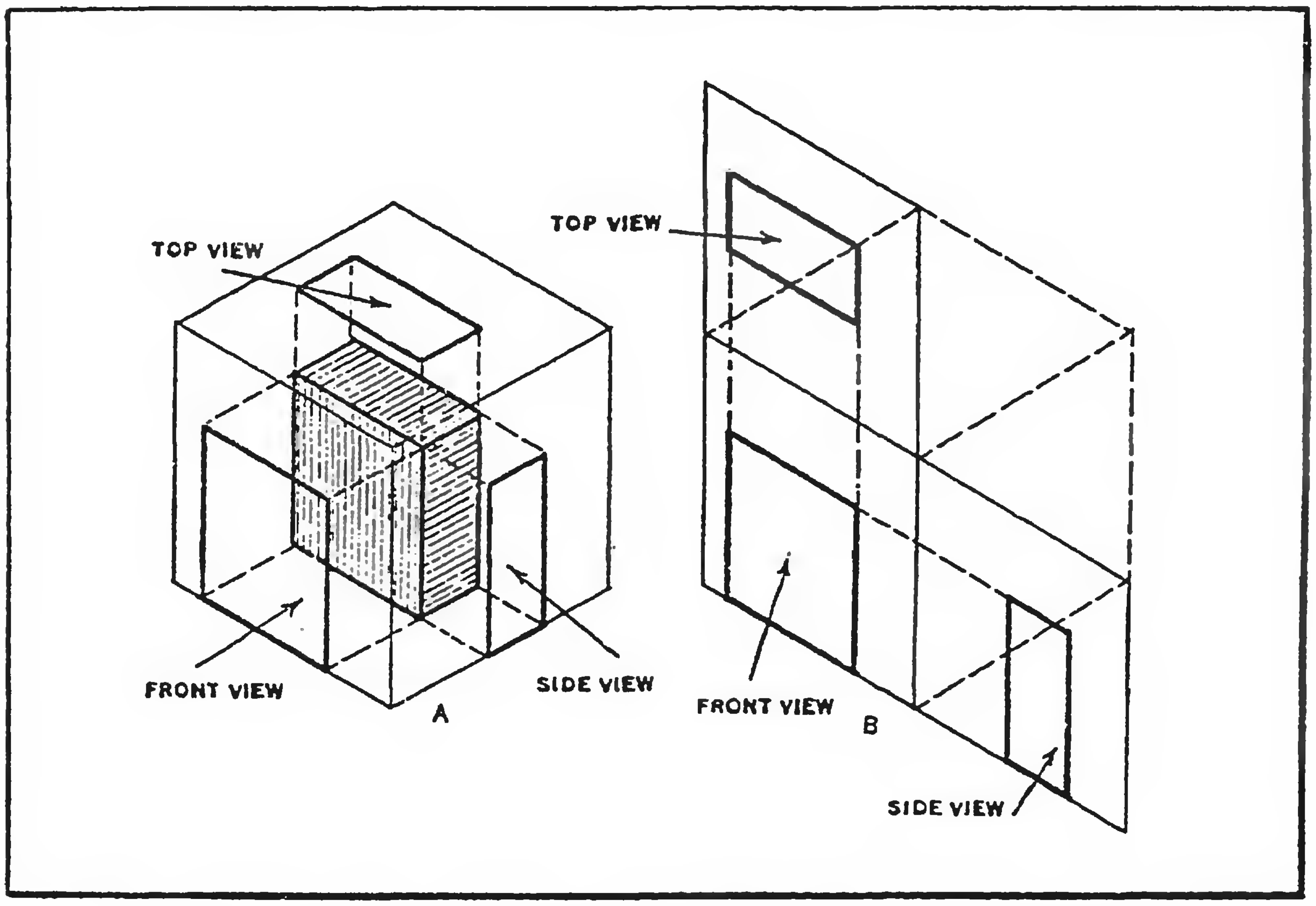


Diagram Illustrating Principle of Orthographic Projection

of the block to the front of the box, as illustrated by the dotted lines, and these four points were joined as shown by the full lines,

the square thus drawn would correspond to the front view. In the same way, if the corners of the side were projected to the side of the box and a rectangle drawn, this would correspond to the side view of the block. The top view is represented as being projected up to the top side of the box in a similar manner. These three views now represent a mechanical drawing made according to the orthographic projection method, but they lie in three different planes and on an actual drawing it is, of course, necessary to place all three views on a flat sheet or so that they all lie in one plane. If it is assumed that the top and right-hand side of the glass box are hinged at the front edges, and that they are turned so as to lie in the same plane as the front side, the views will then appear as shown at *B*.

It will be understood that diagram *A* is intended merely to illustrate the principle of orthographic projection and that, in actually making a drawing of this block, the front view would ordinarily be drawn first to whatever size the block happened to be or to some reduced scale; then lines would be extended or projected for locating the end lines of the sides and top views. The rectangles would then be completed by drawing lines representing the sides on both the top and side views, the distance between these lines corresponding to the thickness of the block.

Number and Arrangement of the Views: A mechanical drawing may show only one side of an object or it may be composed of two or more views. Two or three views are the usual number, although four may be needed and sometimes it is necessary to add separate views or sections of important details. These detail views are frequently used to show some part which is not represented clearly enough in the general views. The views of mechanical drawings are arranged according to a definite plan. In the United States, the general practice is to place the top view above the front view, and the end view next to whatever end it represents. For example, if a view of the left-hand end is considered preferable to a view of the right-hand end, this end view is placed to the left of the front view, thus indicating that it represents the left-hand end or side. If it were considered advisable to show both ends, then a right-hand view would be placed to the right of the front view. In some instances, a bottom view is needed, in which case it is placed below the front view.

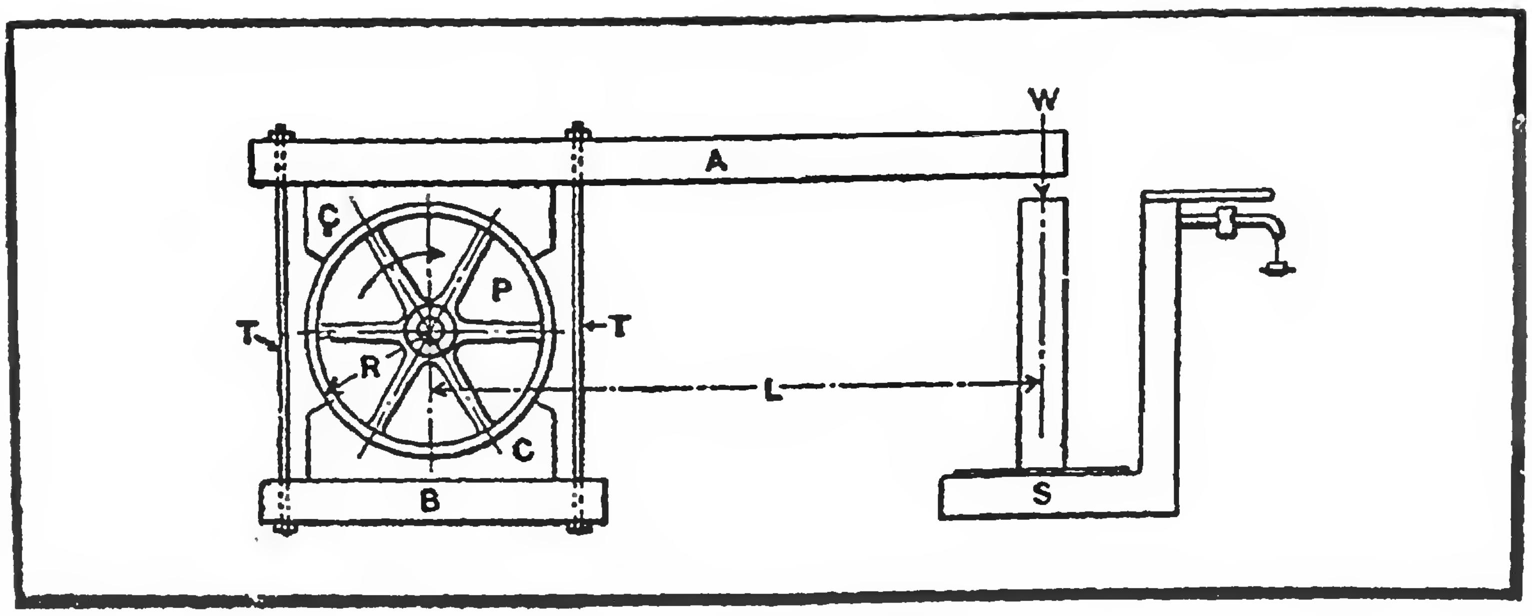
The view obtained by looking at the object from above is known as a *plan* view; that obtained by looking at the object from one of its sides and showing a vertical face is known as an *elevation*, and it may be either a *front elevation* or an *end elevation* (also known as *side elevation*), depending upon whether the view is of the front or side of the part drawn.

Third-angle and First-angle Projection.—When the views are placed with the plan above the front elevation, the right-hand end view to the right and the left-hand end view (when drawn) to the left, this is known as *third-angle projection.* In European countries, it is frequently the custom to use what is known as *first-angle projection.* With this method, the front elevation is placed at the top, the plan view at the bottom, the right-hand end view at the left, and the left-hand end view at the right. The first-angle projection is also generally employed in architectural and structural work, as in drawings of bridges, etc. See Isometric Projection.

Prony Brake. The simplest form of absorption dynamometer is the Prony brake (see diagram). This consists of a wooden beam A and a shorter beam B, connected by the two tie-rods T; fastened to the beams are the two wooden pieces C. These pieces are sawed so that they fit the surface of the pulley P. By tightening the nuts on the tie-rods, the friction between the blocks and the pulley surface is increased. A knife-edge fastened to the beam A rests upon a support which transmits the pressure to the platform scale S. As the pulley revolves in the direction indicated by the arrow, its motion is opposed by the friction of the blocks. The brake absorbs the power generated or transmitted by the machine to which the pulley is attached.

The horizontal distance L between a vertical line through the axis of the pulley, and a vertical line through the knife-edge which supports the brake, is known as the *arm* of the brake. The weight indicated by the scale when the brake is absorbing power is known as the *tare* of the brake. The weight which would be indicated by the scale, if the pulley were absolutely frictionless, is known as the *zero reading* of the brake. The difference between the tare and the zero reading is known as the *brake reading.* In order to determine the zero reading, the nuts are loosened so as to reduce the friction as much as possible, and the pulley is then revolved slowly forward and the scale reading taken. The pulley is then revolved slowly backward and the scale reading again taken. The average of these two readings is the zero reading. If, for any reason, it is not convenient or possible to make these two readings, the nuts on the tie-rods may be loosened until a section of round iron or steel of small diameter can be placed between the rim of the pulley and the friction surface of the upper block, parallel to and vertically over the axis of the pulley. The weight registered by the scale in this case is the zero reading of the brake. The power absorbed by the brake may be determined by the formula:

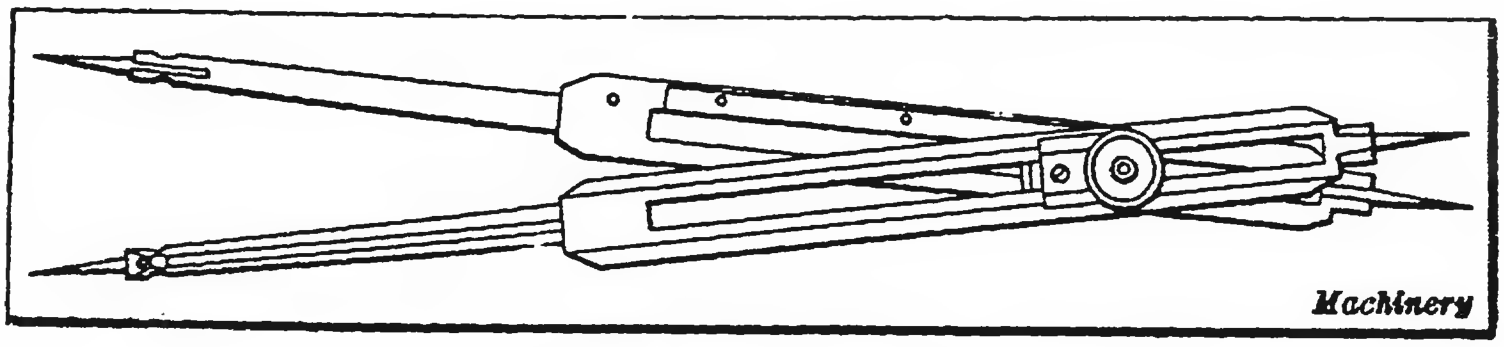
$$\text{H.P.} = \frac{2\pi LNW}{33{,}000}.$$



The Prony Brake

in which H.P. = horsepower absorbed by the brake;
L = length of the brake arm in feet;
N = number of revolutions of the pulley per minute;
W = brake reading in pounds.

Proportion. When two quantities bear such a relation to each other that as one is increased the other becomes greater, or, as one is decreased the other becomes less at the same rate, they are said to be in *direct proportion*. The circumference of round bar stock is *directly proportional* to the diameter of the bar. If the diameter increases, the circumference will increase, and if the diameter is made less, the circumference will be less. If the relation between two quantities is such that as the one increases the other becomes smaller, and as the one decreases the other becomes greater in the same rate, they are in *inverse proportion*. When the relation between two quantities is such that the increase or decrease of one affects the other by a combination of two or more direct or inverse proportions, they are said to be in *compound proportion*. If one man can turn 50 bevel gear blanks in a day of 10 hours, then 5 men can turn 225 blanks in a day of 9 hours The number of blanks turned by one man in 10 hours is in compound proportion to the number turned by 5 men in 9 hours, because the proportion is a combination of the proportion between the number at work and the proportion of the time they are working.

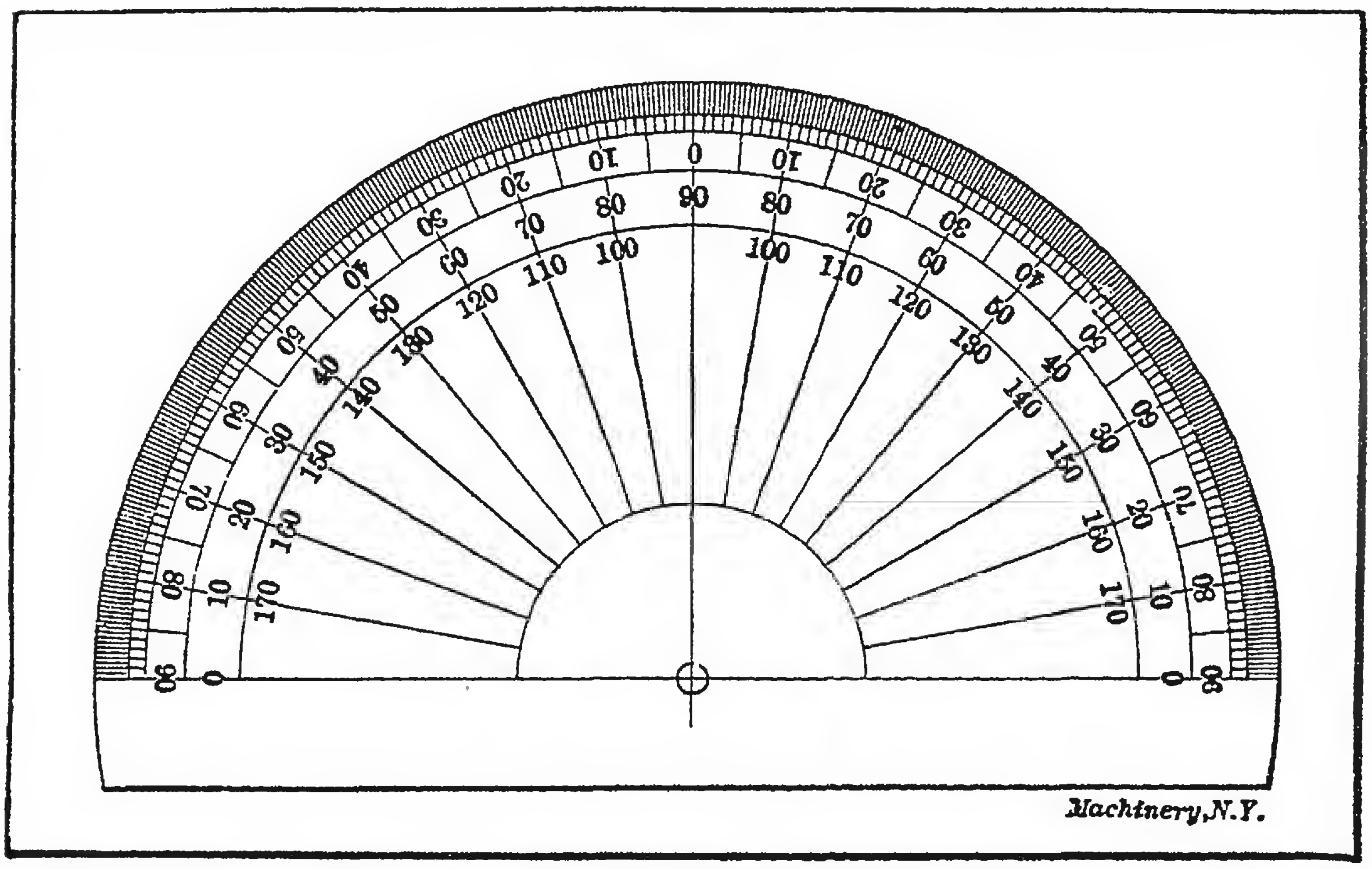


Proportional Dividers

Proportional Dividers. Dividers of this type have slotted legs and a combined clamping screw and pivot which can be changed to any point desired. Thus, the double-pointed legs form practically two dividers, the relative lengths of which are adjustable at will (see illustration). If the pivot screw is so placed that its distance from one point is one-third of the entire length of the legs from point to point, the dividers are set at a proportion of 1 to 2; that is, if the divider legs are opened until the shorter leg points are one inch apart, the points of the longer will be two inches apart. It follows that by shifting the position of the pivot screw any other relative proportion can be obtained. The position of the pivot screw is determined by graduations upon one of the legs, to which a single line upon the sliding pivot block may be adjusted.

Proportional Limit. Proportional limit is the stress at which deformations cease to be proportional to the load. This value is determined with an extensometer.

Protex. A liquid that is brushed or sprayed on surfaces to be protected, which are then covered preferably with so-called "Kraft" paper. Sets quickly to a moisture-proof, tough skin,



Simple Form of Protractor

which is a good insulator for low-voltage current. When the covering is no longer needed, it can be readily peeled off with the Kraft paper, or, if paper is not used, it can easily be pulled off by itself. Metal thus protected can be stamped or pierced with-

out removing the coating. Applied to highly polished, painted, plated, or duco-finished surfaces to protect them from scratches, tarnish, etc.; also sprayed or brushed on parts or assembled machines in storage to prevent rust or corrosion; also used as a coating for equipment in a plant that is not to be used for some time.

Proton. A proton is a stable elementary particle (constituent of matter) which carries a positive charge equal in magnitude to that of the negative charge of the electron, its charge being about 4.8×10^{-10} electrostatic unit or 1.6×10^{-19} coulomb. The mass of a proton is 1.6724×10^{-24} gram or approximately 1836 times the mass of an electron. The nucleus of an atom consists of protons and neutrons, except in the hydrogen atom which has only one proton as a nucleus.

Protractor. The protractor is used by draftsmen either for locating lines at a given angle or for measuring angles between lines. A simple form is shown by the illustration. Some protractors are provided with an arm pivoted at the center and swinging around the circle. The smaller protractors are divided into degrees, while larger ones show half or quarter degrees. Those with a swinging arm are usually provided with a vernier scale by means of which small fractions of degrees, three or five minutes, for example, are read. The type generally used by machinists and toolmakers is known as the *bevel protractor.* It has a straight edge or blade which can be set at any angle with the base or stock; the angle for any position is shown by degree graduations.

Proximate Analysis. In chemistry, a proximate analysis is a quantitative analysis in which the percentages of compounds (but not elements) that make up a substance are determined. For example, in a proximate analysis of coal, the percentages of volatile matter, fixed carbon, moisture, sulphur, and ash are determined.

Prussian Blue. Prussian blue or feric ferrocyanide is a blue amorphous powder used as a pigment in layout fluids. These fluids are employed in coating metals to be marked with scribed lines.

Prussiate of Potash. Same as Cyanide of Potassium. See Cyanide.

Puddled Steel. A slag-bearing steel made by the puddling process, which contains enough carbon to harden when suddenly cooled—a product rarely, if ever, made at the present time.

Puddling Process. The puddling process is used in the manufacture of wrought iron. Pig iron is melted in a puddling fur-

nace where most of the silicon, carbon, phosphorus, and other impurities are separated from the iron. Pig iron melts at about 2100 degrees F., and wrought iron at about 2800 degrees F. The temperature during the puddling process is high enough to melt the pig iron, but not high enough to keep wrought iron in a liquid state. Hence, as soon as the small particles of wrought iron are freed from the excess of carbon, they form a spongy mass in which the small globules of iron are in a semi-plastic state. This mass is divided by the puddler into lumps of about 200 pounds each, which are formed into elongated blooms by a rotary squeezer, and, while hot, are rolled out into "muck bars."

Pulley. The pulleys or wheels used for the transmission of power by belting are made either of cast iron, steel, wood, or a combination of these materials. Aside from the materials used in their construction, pulleys differ principally in regard to the form of the hub, the form of the rim, and the number and arrangement of the arms connecting the hub and the rim. *Cast-iron pulleys* may be either of the solid type, the clamp-hub type. or the slit type. The *solid pulley* is so named because the entire pulley is one solid casting. The *clamp-hub pulley* is a single casting and has a solid or continuous rim like a solid pulley, but differs from the latter in that the hub is split or divided, and it is provided with clamping bolts. When these bolts are tightened, the split hub grips the shaft tightly. Some pulleys of this class are held simply by friction, whereas others have, in addition to clamping bolts, a key or a key and set-screws. The *split pulley* is formed of two separate sections which are bolted together both at the hub and on opposite sides of the rim where the two parts are divided. This form of pulley can be placed between other pulleys on a shaft without removing either the pulleys or the shaft, by simply separating the pulley sections and clamping them together wherever the pulley is required. *Steel pulleys* which are made from steel plate, represent a comparatively modern development in pulley manufacture. The rim is either formed by rolling or by means of rolls and dies; the spokes are also made from sheet stock. These pulleys are of the split type and combine lightness with strength. The weight of one well-known make is about 45 per cent of the weight of a cast-iron pulley of corresponding diameter.

Pulley Crown. The face of a pulley is crowned by making the center larger in diameter than the edges. This is done for the purpose of guiding the belt in a straight line and thereby keeping it in position without using such mechanical means as belt guides or flanges for this purpose. The crowning, however, tends to keep the belt on only when the belt does not slip. A slipping

belt will run off a crowned face pulley more easily than from a straight-faced one. Different authorities recommend very different amounts of crowning. One authority recommends a crown or height at the center of 1/20 of the width of the pulley for leather belting, and 1/150 of the width for cotton belting. Another recommends from 1/16 to ⅛ inch of crown for each foot of width of pulley for high speeds, and ¼ inch of crown for low speeds. A formula which has proved satisfactory is as follows: 1/200 of pulley face $+$ 0.020 inch $=$ height of crown.

Pulley Lathe. The pulley lathe is a special design intended for turning and facing pulleys, gears, flywheels, couplings, and work of a similar nature. A well-known design of pulley lathe has two tool-rests, one located at the front and the other at the rear of the machine. The tool-rests are mounted on compound slides, one of which is utilized for diameter adjustment, and the other for feeding the tool when turning. These slides are carried by a table which swivels in the center and has a series of holes drilled on one side, through which a pin is inserted in order to locate the table at whatever angle may be required to give the desired taper or "crown" on the pulley. The tool-slides feed in opposite directions, so that each tool turns half of the pulley rim.

Pulley Speeds. The following rule for the relation between the sizes of pulleys and the number of revolutions of two shafts can be formulated: The number of revolutions of one shaft multiplied by the diameter of the pulley on the same shaft, divided by the number of revolutions of the second shaft, gives the diameter of the pulley on the second shaft. To obtain the speed of the driven pulley in a compound drive, proceed as follows: Divide product of diameters of driving pulleys by product of diameters of driven pulleys, and multiply quotient by speed of first driving pulley.

Pulley Taps. Originally designed for use in tapping set screw holes in the hubs of steel pulleys. The thread length is approximately equal to that of a regular (standard) hand tap, while the shank is full diameter of the thread and comes in various lengths. Recently the field for this tap has been expanded to meet the demands of those who want hand taps in longer lengths.

Pulsometer. The pulsometer, sometimes known as an aquometer, may be defined as a steam pump which acts partly by direct steam pressure and partly by vacuum. It has two working chambers into which the steam is alternately admitted. A partial vacuum is formed by the condensation of the steam, then water rushes into the chamber on account of the vacuum thus formed.

When the chamber is full of water, the valve opens, steam enters again, and forces the water out into the delivery chamber, the steam condenses as before, causing the inflow of another supply of water, and the cycle is repeated. Two chambers are provided so that one is filled while the other is discharging. The pulsometer has neither rotating nor reciprocating parts. It will raise water to a height of about 26 feet, although it is not advisable to have a lift exceeding 20 feet, and it will force the water, if necessary, to a height of about 100 feet.

Pump. A pump may be defined as a mechanical device or machine designed for elevating or conveying liquids against the action of gravity, or for exhausting air or other gases from a closed vessel. A pump for liquids may be intended primarily for elevating the liquid from a source of supply below the pump up to the pump, or the principal purpose may be to force the liquid either to a much higher level or to some distant point by connecting the pump with suitable pipes. A mechanical device for withdrawing air from a closed vessel is ordinarily classified as a *pump*, but, if designed for compressing air or other gases, it is known as a *compressor* or *blower*.

Pumps are classified either with reference to some characteristic constructional feature or the particular class of service for which they were designed. The common types of pumps may be divided into several general classes, as follows: 1. *Reciprocating pumps* or those having a piston or plunger which is given a reciprocating movement in the pump cylinder. 2. *Centrifugal pumps* having a rotary impeller which, as a result of centrifugal force, causes the water to flow from the center to the periphery of the impeller with increasing velocity, and then out through the discharge outlet. 3. *Rotary pumps* which, according to the general usage of the term, differ from the centrifugal pumps in that the water or other fluid is forced through the pump by the direct application of pressure from rotating pistons or impellers and independently of centrifugal action. 4. Pumps in which the fluid is moved by the direct application of steam or compressed air and without employing a reciprocating piston or rotating impeller. In each of these four general classes, there are many different types.

Pump, Air or Vacuum. See Air or Vacuum Pump.

Pump Displacement. The displacement of a pump is equivalent to the "effective area" of the pump piston or plunger multiplied by the length of the stroke, or it is the volume included in a complete stroke. To determine the displacement in cubic inches per minute, multiply the effective area of the piston or plunger

in square inches by the length of the stroke in inches and this product by the number of *discharging* strokes per minute. The effective area of a piston or plunger will be reduced somewhat on one side by the area of the piston-rod, except in the case of an outside end-packed plunger pump or a single-acting pump. Ordinarily the piston-rod area would not need to be considered.

Pump Lift. See Lift of Water Pumps.

Pump Suction. "Suction" is a term commonly applied to pumps to denote a decrease of atmospheric pressure within the inlet pipe and cylinder of a pump, as compared with the normal atmospheric pressure. During the suction stroke of a pump, which lifts water or some other liquid up to the pump cylinder from a lower level, the movement of the piston creates a partial vacuum within the cylinder on the inlet side, but as the normal atmospheric pressure is acting at the same time on the outer surface of the water with which the inlet or suction pipe connects, the water is forced upward because of the unequal pressure. What is commonly known as "suction," therefore, is, in reality, the forcing of water to a higher level by normal atmospheric pressure acting on a column of water connecting with a closed chamber or cylinder in which a partial vacuum has been formed. See Lift of Water Pumps.

Pump Suction and Discharge Pipes. See Suction and Discharge Pipes.

Pump Valve Lift and Area. In the design of pump valves, the combined area should be large enough to prevent excessive velocity and friction when the water or other liquid is passing through the valve seat; the suction valves should open easily and with little pressure, as otherwise, the atmospheric pressure would not overcome the resistance, especially if the vertical height from the source of supply to the pump cylinder were considerable; the lift of the valves should be small, to prevent excessive slip or leakage while the valves are closing; the valves should close rapidly, be tight when closed, durable, and easily replaced. Evidently there must be a compromise in the design of valves. For instance, stiff springs would close the valves quickly, but increase the pressure required for opening them; a high lift would be conducive to a free flowing movement of the water, but a low lift is desirable to prevent excessive losses through slip; large conical seats would provide straight passages for the water and reduce the frictional resistance to the flow, but would require large heavy valves and high lift. The general practice is to use a number of small valves and flat seats instead of the conical form, in order to reduce the amount of lift, although conical

seats are sometimes used in connection with wing valves, etc. The lift of disk valves is usually about ¼ inch, regardless of the diameter. A wing valve having a 45-degree seat requires 40 per cent more lift than a flat valve to obtain a corresponding area of opening. The total valve area usually varies from 45 to 50 per cent of the plunger area, although it may be as low as 30 per cent and as high as 60 per cent, depending upon the speed at which the pump is to operate. The maximum velocity of the water while passing through the valves should be about 225 feet per minute. By "valve area" is meant the area of the unobstructed opening or free passageway through the seats.

Pump Valve Spring Pressures. For discharge valves, the spring pressure should equal approximately from 0.005 to 0.01 times the water pressure, with a maximum pressure of 5 pounds per square inch. For suction valves, when there is a suction lift, the pressure should equal from 0.25 to 0.5 pound per square inch.

Punch. A "punch," as the term is applied in pressed-metal work, is that part of a press tool which enters into an opening or cavity formed in the die section, as in drawing, forming, or blanking. The punch usually is the upper member, being attached to the press slide or ram, but it may be the lower member, as in the case of press tools of inverted design. Whenever the function of the upper and lower members is identical, as, for example, in embossing the sides of coins or medals, the upper die section would ordinarily be called the punch merely because the punch member of most dies occupies the upper position; nevertheless, it is form rather than location which, in general, is the distinguishing feature between the punch and its mating die.

Punch and Die Clearance. There is a difference of opinion among diemakers as to the method of designating clearance. The prevailing practice of fifteen firms specializing in die work is as follows: Ten of these firms define clearance as the space between the punch and die on *one side*, or one-half the difference between the punch and die sizes. The remaining five firms consider clearance as the total difference between the punch and die sizes; for example, if the die is round, clearance equals die diameter minus punch diameter. The advantage of designating clearance as the space on each side is particularly evident in the case of dies of irregular form or of angular shape. While the practice of designating clearance as the difference between the punch and die diameters may be satisfactory in the case of round dies, it leads to confusion when the dies are of special unsymmetrical forms. The term "clearance" should not be used in specifications without indicating clearly just what it means. According to the practice of one manufacturer of dies, the term "cutting clearance" is

used to indicate the space between the punch and die on each side, and the term "die clearance" refers to the angular clearance provided below the cutting edge so that the parts will clear as they fall through the die.

Amount of Clearance: The amount of clearance between a punch and die for blanking and perforating is governed by the thickness and kind of stock to be operated upon. For thin material such as tin, for example, the punch should be a close sliding fit, as, otherwise, the punching will have ragged edges, but for heavier stock there should be some clearance. The clearance between the punch and die in cutting heavy material, lessens the danger of breaking the punch and reduces the pressure required for the punching operation. For brass and soft steel, most dies are given a clearance on one side equal to the stock thickness multiplied by 0.05 or 0.06; but one-half of this clearance is preferred for some classes of work, and a clearance equal to the stock thickness multiplied by 0.10 may give the cleanest fracture for certain other operations such, for example, as punching holes in ductile steel boiler plate.

Punches, Quill. See Quill Punches.

Punching Machine Spacing Table. See Spacing Table.

Punching Pressure. The following approximate rule may be used for rapidly finding the pressure in tons required for punching circular holes in sheet steel: Multiply the diameter of the hole, in inches, by the thickness of the sheet steel, and multiply this product by 90. The result is the pressure, in tons, required. To find the pressure required for punching holes in brass, multiply the diameter of the hole by the thickness, and multiply this product by 75. It will be understood that the foregoing rules give only a rough estimate of the punching pressure, since the latter depends upon the composition of the steel or other material to be punched, and may be varied by shear given to the cutting edges of the punch or die.

Punching Tools and Machines. The tools used for punching rivet and bolt holes in metal plates, angle irons, I-beams, channels, etc., vary in size and design from the small hand-operated types to the large power-driven machines found in boiler shops, ship yards, and similar places. The term "punch" is commonly applied to tools and machines of this class, although, strictly, the punch is that part of the tool or machine which in conjunction with the die, actually performs the punching operation. Some punching machines are designed to punch holes exclusively, whereas other machines are adapted either to punching or shearing by simply attaching suitable tools.

Punch Press Rating. See Power Press Tonnage.

Push-Spindle Grinding Attachment. This is a grinding attachment for bench lathes in which the spindle, which is free to move in a lengthwise direction, is held by two bearings, and, when grinding, is transversed by hand, the spindle being driven by a round belt from an overhead countershaft. See Grinding Attachment, Push-spindle.

Puzzolan Cement. Same as Pozzuolanic Cement.

Pyrite. Pyrite is an iron ore containing 46.7 per cent of iron. In its chemical composition it is a sulphide, FeS_2, having a yellow color and producing a green or brownish-black streak on a porcelain plate. The specific gravity of pyrite varies from 4.8 to 5.2, and the hardness on the Mohs's scale, from 6 to 6.5. This ore contains too much sulphur to be used directly for the production of iron and is, therefore, first desulphurized, sulphuric acid being extracted from the ore as an important product. The ore often contains copper, and, after the sulphuric acid has been extracted, the copper is obtained by means of the so-called "wet process," after which the ore is used as an iron ore. There are large deposits of this ore and it is likely that, when the richer deposits of oxidized ores have been exhausted, it will gain considerable importance in the iron industry.

Pyro-Metallurgical Process. This is a method for obtaining a metal from its ores by means of smelting. See Dry Process.

Pyrometer Paste. Salt mixtures made in the form of paste are sometimes used for determining temperatures. Different pastes of various melting points can be placed along a steel bar and inserted in the furnace, retort, flue, or other point where it is required to make a temperature determination, and, by noting which paste melts and which does not, the temperature may be determined.

Pyrometers. A pyrometer is any device used for measuring temperatures from about 500 degrees F. and higher. There are a number of pyrometers based on widely different principles and of entirely different construction. The most commonly used pyrometers are of the *thermo-electric* type. In this type, temperature variations are determined by the measurement of an electric current generated by the action of heat on the junction of two dissimilar metals. The thermo-couple, consisting of two pieces of dissimilar metals, is placed at some point within the furnace and is connected by wires with a meter or indicator which may be close to the furnace or in some other part of the plant. That end of the thermo-couple which extends into the heated

chamber is known as the "hot end," and the two pieces of dissimilar metals do not touch except at this hot end. The opposite or "cold ends" which are free or separated are connected by wires with whatever indicating or recording apparatus is installed. When the hot end is heated, a feeble electric current is generated. The electromotive force thus developed depends upon the kind of metal of which the thermo-couple is made, and upon the difference between the temperatures of the hot and cold ends. The current is conducted by wires leading to the meter or indicating part of the pyrometer outfit. The instrument may be calibrated or graduated to give readings directly in degrees.

The method of utilizing the current to indicate degrees of temperature varies with pyrometers of different makes. Many pyrometers are so designed that the indicating hand or pointer is displaced, by the direct action of the current upon a moving element, an amount depending upon the strength of the current generated. In this case, the indicating instrument is a form of galvanometer or millivoltmeter. As a feeble current is generated, a sensitive instrument is required, and one of the important features is the method of arranging and supporting the moving element so that it is actuated by slight changes in the strength of the current.

The variation in electric conductivity due to changes in temperature is the principle upon which the *resistance pyrometer* is based. This type is very accurate for temperatures below 1600 degrees F., but should not be used continuously for higher temperatures. The maximum temperature is about 2200 degrees F.

Radiation pyrometers measure radiated heat and are adapted for very high temperatures. The Fery radiation pyrometer is practically a reflecting telescope having a concave mirror which focuses the radiant heat of the object upon the "hot" junction of a small thermo-couple. There is a diaphragm for reducing the aperture when the instrument is pointed at a very hot object, in order to prevent overheating the thermo-couple. With the Brown radiation pyrometer, the rays of heat from the furnace or molten metal which enter the pyrometer tube are reflected from a concave mirror onto a sensitive thermo-couple, and the temperature is indicated on a millivoltmeter, graduated in temperature degrees, the same as a thermo-electric pyrometer. No part of the instrument is inserted in the high heat to be measured. If the temperature of a furnace is to be measured, the tube is either held on a tripod or in the hand, and is pointed toward the door of the furnace. The temperature can then be read off on the indicator.

There are several classes of *optical pyrometers*. One type in-

dicates the temperature by heating the filament of an electric lamp to the same color as that of the incandescent body, the temperature of which is required. The small low-voltage lamp is placed inside a tube through which the heated object is observed. To determine the temperature, the current for the lamp is so regulated (by means of a rheostat) that the color of the lamp filament corresponds to that of the heated object which is observed through the instrument. The current then being consumed is indicated by a milliammeter, and the corresponding temperature is determined. There are several other types of optical pyrometers. These pyrometers may be used to estimate the highest temperatures, and may be used for temperatures above 3000 degrees F., both in laboratory and industrial work. See also Potentiometer.

Pyrometers, Automatic Control Type. The pyrometer that automatically controls furnace temperatures is so arranged that the moving element of the instrument not only indicates the temperature by its position relative to a scale, but by combined mechanical and electrical apparatus, controls the temperature, within certain limits, by regulating the heat supply. The pyrometer can be set for any temperature desired within certain maximum and minimum limits. If the furnace is electrically heated, the temperature may be regulated by solenoid-operated switches, which either open and close the main circuit, or are used in conjunction with rheostats. In the case of gas or oil-fired furnaces, electrically or pneumatically operated controlling valves or dampers are employed, the opening and closing of these valves being governed by the pyrometer.

Pyrometers, Indicating. Many of the pyrometers used in heat-treating plants may be designated as the "indicating" type, since the temperature variations are shown by the position of a hand or pointer relative to a graduated scale. The indicating instrument may be located close to the furnace or in some central station or controlling room. When it is by the furnace, the furnace operator controls the temperature either according to his experience with similar work, or possibly by reference to data previously recorded. This is a common method in small plants, but where a large heat-treating department is installed, a centralized system of control is quite general.

Pyrometers, Recording. A recording pyrometer is provided with some kind of marking device which traces either a continuous or a dotted line upon a chart graduated with reference to temperature and time. By referring to one of these charts, the temperature at any period within the range of the chart is shown graphically. The chart may be graduated in minutes of time and

may cover a total range of, say, two hours, or the main divisions may represent hours and cover either a twelve-hour period or a twenty-four-hour day. Pyrometers are also made to give a continuous record over long periods. These charts differ in form, some being circular disks and others of rectangular shape. The charts or records of temperature variations obtained by means of recording pyrometers are not only valuable for future reference, but also enable the superintendent, foreman, or attendant to watch readily the operation of any furnace by inspecting the chart whenever convenient. Besides showing the temperatures, the charts indicate the general trend of any changes which may occur. The use of recording instruments tends toward greater uniformity in the quality of heat-treated products.

Multiple Recorder: Where a heat-treating plant contains two or more furnaces, a pyrometer may be installed that will record automatically on a chart temperature variations in each furnace to which it is connected. This type of pyrometer is generally used when the heat-treating process requires a half-hour or more for its completion. The pyrometer may be designed especially for multiple recording or have an auxiliary connecting or switching device. One type of multiple recorder will produce from two to eight records on one chart, and when four, six, or eight records are needed, these are printed on the chart in different colors to avoid confusion.

Pyrometers, Signaling. In order to dispense with manual control of temperature signals from a central station, automatic signaling pyrometers have been developed. One type of signaling pyrometer is so arranged that the pointer is depressed at intervals upon contacts corresponding to the red, white, and green lights. The particular contact upon which the pointer is depressed depends upon the position of the pointer which, in turn, varies according to the temperature. The three contacts may be adjusted to a position corresponding to the temperature to be maintained. This type of instrument, when provided with a suitable switching mechanism, may be arranged to operate batteries of lights for different furnaces.

Pyrometer, Thermo-Couple. A type of pyrometer in which the basic temperature measuring element is a thermo-couple is widely used in conjunction with steel heat-treating processes. A thermo-couple consisting of two pieces of dissimilar metals is placed at some point within the furnace and is connected by wires with a meter or indicator which may be close to the furnace or in some other part of the plant. That end of the thermo-couple which extends into the heated chamber is known as the *hot end,* and the two pieces of dissimilar metals do not touch except at

this hot end. The opposite or *cold ends* which are free or separated are connected by wires with whatever indicating or recording apparatus is installed. When the hot end is heated, a feeble electric current is generated. The current is conducted by wires leading to the meter or indicating part of the pyrometer outfit. The instrument may be calibrated or graduated to give readings directly in degrees F. or C.

Either *base metal couples,* which are made of some nickel alloy or of iron-constantin, or *rare metal couples,* usually of platinum in conjunction with a platinum alloy, may be utilized. The base metal couples have the advantage of generating an electromotive force which is several times as great as that derived from a platinum alloy couple; consequently, the indicating instrument can be made less delicate and is not so likely to become deranged. Another advantage is that for a unit increase in the temperature of a base metal couple there is approximately a uniform increase in electromotive force, the relation between the two being represented by a line that is nearly straight. The result is that the pyrometer has graduations or divisions that are practically equal or even, which is preferable to a scale having short divisions for the lower temperatures and longer ones for the higher temperatures, or vice versa. Still another advantage is that the increase of resistance due to an increase of temperature is very low as compared with a rare metal couple. It is essential that all thermocouples which may be used at different times in conjunction with a pyrometer generate the same electromotive force for a given temperature; in other words, the thermo-couples should be interchangeable. Without this uniform relationship between the temperature and the electromotive force generated, the pyrometer readings will not be correct. In addition to this quality of uniformity or accuracy, a reasonable degree of durability is also important.

Q

Quadratic Equation. A quadratic equation is one in which the unknown quantity is contained in the second power or in the first and second powers. A quadratic equation is sometimes called an equation of the "second degree." See Equations.

Quadric Inch. The expressions "quadric inch" and "quadric foot" are sometimes used in connection with values denoting the moment of inertia. The moment of inertia is expressed by the fourth power of a length dimension; hence, the expression "quadric inch, foot," etc., according to whether the inch or foot is used as the unit length. In expressions containing the moment of inertia, the quadric dimension is frequently abbreviated $in.^4$, $ft.^4$, etc. The expression is not very commonly used.

Quadrivalent. Quadrivalent, also known as *tetravalent,* is a term used to indicate that one atom of an element will combine with four atoms of another element.

Qualitative Analysis. In chemistry, qualitative analysis is the resolution or division of complex chemical substances into their elements, when only the kind of constituent elements are determined, but the percentage contained of each is not of importance. See Chemical Analysis.

Quality Control. In its broadest sense, a quality control system must be concerned with all of the steps taken to regulate the variables in manufacturing operations which affect the excellence of the end product. These variables include materials, machines, workers and manufacturing conditions. In this broader sense, quality control is as old as industry itself. From the beginning of industry, manufacturers have desired to maintain high quality and to improve their products. However, the older rule-of-thumb methods are now giving way to more exact quality control procedures based on statistical methods and probability.

Statistical quality control is a management tool aimed at meeting the common interest of producers and consumers in producing usable articles as economically as possible. Statistical methods are techniques for collecting, presenting, analyzing and interpreting numerical data. In statistical quality control, these techniques are applied to inspection and test data for

setting standards and checking adherence to them, so as to achieve maximum economy in manufacturing operations.

In statistical quality control, the product to be inspected, if not a continuous item such as cloth or paper, is divided into equal size "lots" of a given number of units—100, 1000, 10,000 etc. From each of these lots a number of units—constituting a portion or *sample* of the lot—are taken at random and these are measured or inspected according to the specification requirements. Each unit is accepted or rejected according to whether or not it falls within the dimensional limits or meets the specifications called for. According to the number of items in the sample that are accepted (or rejected) a decision is reached to accept or reject the lot as a whole. This decision is based on standard statistical sampling tables which show for a given size lot and desired level of quality what size of sample should be used and what the acceptance number (minimum number of units in the sample which must be accepted if the lot is to be accepted) and rejection number (minimum number of units in the sample which must be rejected if the lot is to be rejected) should be.

Under other plans—one is sequential sampling—several samples are drawn in succession, a decision being made after the drawing of each sample to accept the lot, to reject the lot, or to draw an additional sample.

There are sampling procedures other than lot-by-lot sampling. For example, there is a procedure in which the inspector is required to inspect a sequence of consecutive items. Such a procedure involves continuous sampling from the production line and is applicable when identical lots are not available.

One of the reasons for the growing acceptance of statistical quality control is the realization that not only is a 100 per cent fully conforming product generally impossible to obtain, but also the acceptance of nothing but fully conforming product is virtually impossible to assure by any reasonable inspection system. Human error, fatigue, or mechanical wear not only serve to prevent the production of 100 per cent conforming products but also serve to prevent 100 per cent perfect inspection, i.e. rejection of all non-conforming items and acceptance of all conforming items. Practical considerations of end use seldom require absolute perfection in every single item. Hence, a practical inspection system such as that provided by statistical quality control is based on the premise that a reasonable allowance for non-conformance is necessary and desirable.

The allowance for non-conformance is expressed in terms of maximum per cent defective or maximum defects per 100 units which will be acceptable and is called Acceptable Quality Level or AQL. Sometimes this nominal value is taken to be the

poorest average level of quality which is to be tolerated in the product under inspection.

Quantitative Analysis. In chemistry, quantitative analysis is the resolution or division of complex chemical substances into their elements when both the constituent elements and the percentages of each that are contained in the original substance are determined. See Chemical Analysis.

Quarter Hammer. This is a small sledge hammer weighing less than eight pounds. See Sledge Hammers.

Quartering Machine. A quartering machine is a special design of horizontal boring machine that is employed exclusively for boring the crankpin holes in pairs of locomotive driving wheels. The holes in each pair of wheels must be 90 degrees apart and they are bored after the wheels are forced on the axle. The pair of wheels is placed between the centers of the quartering machine, and the holes are bored by two short boring-bars. One bar is located on each footstock or center base, and it is carried by a slide that is adjustable. The angle between the ways upon which the slides are mounted is 90 degrees, so that the angular distance between the crankpin holes is also 90 degrees, irrespective of the adjustment of the boring-bars which is made to conform to the radius of the crankpin circle. The crankpins in each pair of driving wheels are placed 90 degrees apart in order that one side will be developing maximum power when the other side of the locomotive is passing the dead center position, thus equalizing the distribution of the power developed and making it impossible for both sides of the locomotive to be on the dead center at the same time.

Quarternary Alloy. A quarternary alloy is an alloy consisting of four elements. When applied to steel, such an alloy contains, in addition to iron, three alloying elements. Carbon is one of these, and the other two may be chromium and nickel, silicon and manganese, etc.

Quarter-Phase Circuit. The expression "quarter-phase" circuit, also known as "two-phase" circuit, is used to characterize a combination of two circuits, energized by alternating electromotive forces which differ in phase by a quarter of a cycle—that is, by 90 electrical degrees.

Quarter-Turn Guide. A quarter-turn guide, in rolling mill practice, is a mechanical means for turning a bar, that has passed through one pass in a rolling mill, through an angle of 90 degrees before it passes through the next pass in a continuous mill.

Queen's Metal. Queen's metal is a tin-antimony-copper bearing alloy containing, in addition to the metals mentioned, a small percentage of either zinc or bismuth. One composition of the metal contains 88.5 per cent of tin, 7 per cent of antimony, 3.5 per cent of copper, and 1 per cent of zinc. Another composition contains 88.5 per cent of tin, 7 per cent of antimony, 3.5 per cent of copper, and 1 per cent of bismuth. Owing to the high percentage of tin, the metal is rather expensive, but, at the same time, the high tin content makes it a high-grade bearing metal.

Quenching Apparatus. When steel parts are heated and then quenched for hardening, excessive distortion may occur, especially if the cooling is not uniform. To prevent such distortion, special fixtures, quenching presses or quenching machines are used for some classes of work. Quenching apparatus may be applied in hardening circular saws or other disk-shaped parts, ring gears or other gears, slender shafts, etc. Some apparatus is designed to prevent distortion by holding the work, while quenching, between rigid clamping members. It is preferable, however, to *prevent* distortion as far as possible, by control of the quenching medium. One type of machine for slender shafts or similar parts is designed to insure uniform cooling by rotating the work rapidly as it is being immersed.

Quenching Press: The Gleason quenching press is designed to minimize distortion especially in hardening rear axle driving gears or ring gears. When the quenching press is used, the gears are held round and flat, not by great pressures but by control of the oil circulation and by the variable pressures on the bore and other sections of the gear. In this way no strains are set up and the true shape of the gear is maintained by natural laws.

After placing the gear on the lower die, a four-way air valve is opened and the upper die holder is started on its downward stroke. The pilot end enters into a segmental bushing and brings the gear approximately to the center of the machine. A tapered cone on the pilot enters the bushing, and bears on the correspondingly tapered portions of segments of the bushing. The segments are pressed outward until they center and "round up" the bore of the gear after which the upper die which has been made to suit the shape of the gear, bears on the top of the gear to hold it flat. Thus the gear is brought true while in a plastic condition.

The pressure on the upper die holder increases and submerges the lower die holder and gear under the oil. In descending the fresh oil is forced through the teeth of the gear at a high rate. The gear is free to either shrink or expand but it is always held round and flat. A reverse movement of the four-way air valve

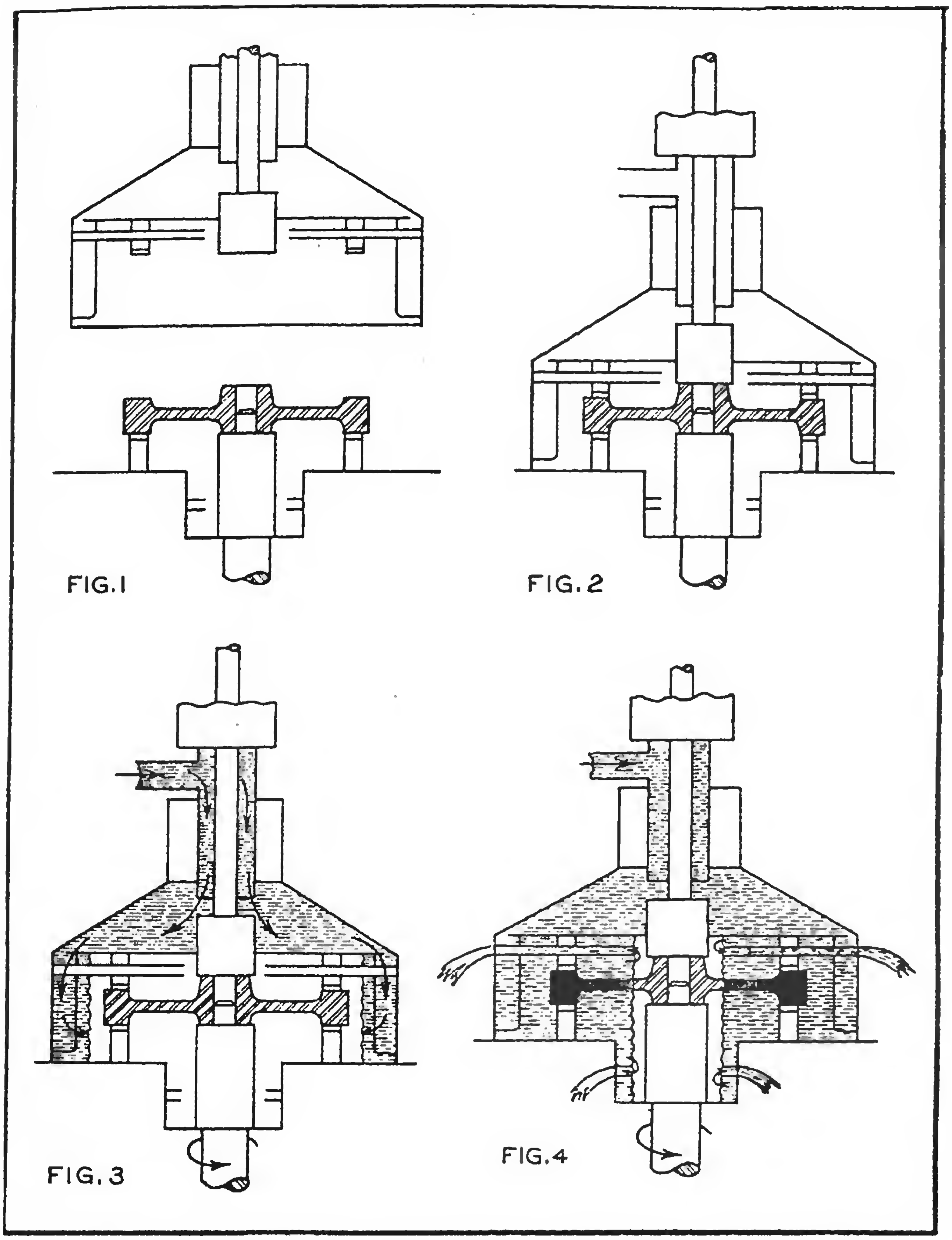
after a short interval raises the upper die holder clear of the oil and gear, and one cycle of the machine is completed.

Centrifugal Quenching Machine: A Hannifin quenching machine that employs centrifugal force to apply the coolant in such a manner as to reduce distortion of circular or disk-shaped parts is designed to apply a large volume of quenching fluid at a uniform, controlled temperature. The machine is adapted for quenching a wide variety of parts, including disks, flat cams, rings, bearing races, and similar work.

The heated part, such as the gear indicated in cross-section in Fig. 1, is placed on the lower fixture in the machine. The insertion and removal of the work at the end of the automatic cycle of operation is the only handling required. The upper and lower holding fixtures are designed to meet individual requirements of the part to be quenched. A mandrel for centering may be provided, and a certain amount of control of the quenching action may be obtained when desirable, through the design of suitable fixtures. The holding fixtures are automatically operated, and in closing, provide a mechanical straightening effect or alignment of the hot part. Referring to Fig. 2, it will be noted that the hub of the gear, located by a pin on the lower part of the fixture, is held in place by a plunger in the upper fixture, and that pins in both the upper and lower fixtures clamp or hold the rim of the gear against warping.

The upper holding fixture is surrounded by a circular quenching chamber, which, when brought down over the work, provides a circular container for the quenching fluid, as shown in Fig. 2. When in the closed position, the entire assembly of quenching chamber, holding fixture, and hot part is rotated by means of a motor drive. The quenching fluid is introduced at the outer edge of the revolving container, as shown in Fig. 3.

The oil is introduced in controlled volume and at a uniform and accurately controlled temperature. The rotation and the control of the coolant volume produce a revolving "doughnut" or ring of quenching oil around the circumference of the chamber. As the volume of oil is increased, the hole in the ring of oil contracts or is reduced, as shown in Fig. 4, the quenching action or effect having advanced rapidly from the circumference of the part inward or toward the center. The oil flows out of the revolving container, under controlled conditions, so that uniformity of temperature is maintained by fresh oil. Sectional quenching under controlled conditions is easily obtained, allowing the center of the part to remain hot and unquenched, as indicated by the cross-sectioned hub of the grear shown in Fig. 4. The



Diagrams Illustrating Application of Hannifin Centrifugal Quenching Machine to the Hardening of Gears

quenched part of this gear, shown in solid black, is hardened. while the hub portion, shown in cross-section, remains soft.

Quenching Baths. Quenching consists in plunging heated steel into a bath thus cooling it quickly. By this operation the structural change caused by the heating seems to be "trapped" and permanently set. Were it possible to make this cooling in-

stantaneous and uniform throughout the piece, it would be perfectly and symmetrically hardened. Clear cold water is commonly employed for ordinary carbon steel, and brine is sometimes substituted to increase the degree of hardness. Sperm and lard oil baths are used for hardening springs, and raw linseed oil is excellent for cutters and other small tools. The effect of a bath upon steel depends upon its composition, temperature, and volume. The bath should be amply large to dissipate the heat rapidly, and the temperature should be kept about constant, so that successive pieces will be cooled at the same rate. Greater hardness is obtained from quenching in salt brine and less in oil, than is obtained by the use of water. This is due to the difference in the heat-dissipating qualities of these substances. High-speed steel is cooled for hardening either by means of an air blast or an oil bath. As a general rule, water should not be used for high-speed steel. Various oils, such as cottonseed, linseed, lard, whale oil, kerosene, etc., are also employed; many prefer cottonseed oil. Linseed has the objection of becoming gummy, and lard oil has a tendency to become rancid. Whale oil or fish oil give satisfactory results, but have offensive odors, although this can be overcome by the addition of about three per cent of heavy "tempering" oil.

Quenching Baths, Alkaline. Alkaline solutions cool steel through the critical range or from the hardening temperature to the black stage at a slower rate than oil, which governs the hardness of the steel. In consequence, the use of alkaline solutions gives the least amount of hardness possible to the work when quenching in a liquid to the cold stage. The loss in hardness is compensated for by the toughness obtained and the elimination of the tendency to warp. When the hot steel is plunged into the bath, the "shock" or rapidity of cooling is lessened and the hardness of the case of the steel is thereby reduced; hence, the strains, etc., in the main bulk cannot bend it to a position of strain equilibrium. Alkaline baths are adaptable to treating steel parts such as axles, etc., when certain physical properties are desired. In case-hardening, alkaline solutions are well adapted for core refinement of delicate parts that would warp excessively if quenched in a faster cooling medium. Materials employed in preparing alkaline quenching solutions are lye, soda ash, soap, etc., and these are used in various amounts according to the final results desired. Alkaline solutions are not generally used, for the reason that, with the different grades of steels that can be obtained, a grade can almost always be selected that will give the desired physical properties by quenching in oil or water.

Quenching Baths, Oil. Oil is used extensively as a quenching medium, since it gives the best proportions of hardness, toughness, and warpage for standard steels. Fish and cottonseed oils have been supplanted to a great extent by special compounded oils of the soluble type. The soluble properties enable the oil to make an emulsion with water, which constitutes a slight advantage, because if water gets into the oil it combines with it to form a medium which cools the work slightly faster than oil alone. In non-soluble oils, the water does not emulsify with the oil, but goes to the bottom of the quenching tank, and as the hot steel passes through the oil to the water it receives unequal hardening strains. A good quenching oil should possess a flash and fire point sufficiently high to be safe under the conditions used, and 350 degrees F. should be about the minimum point. Its viscosity should be such as to allow it to drain readily from the work and circulate itself freely by a thermo-syphon action. The specific heat of the oil regulates the hardness and toughness of the quenched steel, and the greater the specific heat is, the harder the steel will be. Viscosity must also be considered in this respect to some extent. Specific heats of quenching oils vary from 0.20 to 0.75, the specific heats of fish, animal, and vegetable oils usually being from 0.2 to 0.4, and of soluble and mineral oils, from 0.5 to 0.7. The oil should not contain water, should not gum in use, should not be of a disagreeable odor, become rancid, or have a skin-drying effect on the bodies of the workmen. A great many concerns use paraffin and mineral oils for quenching, while a few use crude fuel oils.

Oil Bath Cooling Methods: Keeping the quenching bath cool is important when using oil, and there are three ways of doing this: (1) By using a large quantity of oil. (2) By circulating the oil past colder objects. (3) By passing colder liquids in pipes through the oil. When using large quantities of oil, the oil will retain approximately its surrounding temperature if there is one gallon used for every pound of steel quenched per hour, and the circulation of the oil past the steel is about one gallon per hour. The oil circulation may be accomplished by the agitation of the oil caused by quenching the work and by the thermo-syphon action of the oil, or by storing the oil in a separate tank and pumping to and from the quenching tank.

When circulating the oil past colder objects, the oil is pumped from the quenching tank through a pipe to the cooler. The cooler may be a brine tank cooled by an ammonia refrigerating system; a reversed water heater in which the oil passes through many lengths of piping about which cold water flows; a series of metal sheets set at angles on which the oil is sprayed and allowed to flow from one to the other in a downward zig-zag motion after

which it is collected and pumped back to the quenching tank; or an open tank in which half of the periphery of many revolving disks are placed in the oil, and air is blown over the exposed disks which are covered with a film of oil as they revolve. When passing colder liquids in pipes through the oil, the oil itself is not circulated. Pipes may be laid in the bottom or at the sides of the tank through which cold water can be forced. Cold brine from an ammonia refrigerating system is used in large installations of this type.

Quick-Break Lever Switches. A quick-break lever switch is a plain lever switch with each pole equipped with an auxiliary blade pivoted to the main blade and so arranged that the auxiliary blade will remain in contact in the contact clip until the main blade has been opened to a certain predetermined amount. Then the auxiliary blade is forced out of contact by an arrangement on the main blade, and quickly follows the main blade due to the action of a spring. The current in the circuit when the switch is opened under load is broken on the auxiliary contacts which are moving rapidly when they leave the contact, thus quickly rupturing the arc without damage to the main blade.

Quick Change-Gears. A combination of gears permanently assembled in a machine tool and so arranged that ratio changes are obtained merely by the shifting of levers. For example, on most lathes, the changes of feed for turning and screw cutting are obtained by means of a system of gearing which enables the changes to be made rapidly by shifting one or more levers. A table or index plate, attached to the machine, shows what rates of feed or pitches will be obtained for different positions of the levers.

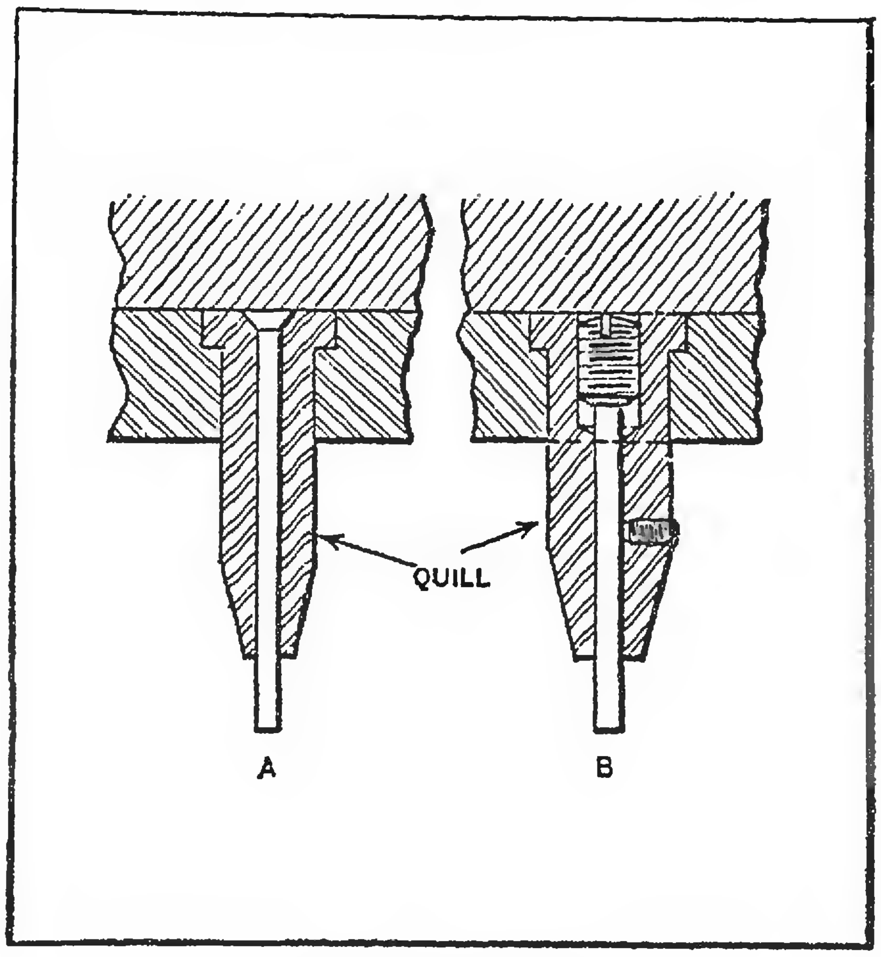
Quicksilver. See Mercury.

Quill for Bench Lathes. A quill is an auxiliary spindle that is used on bench lathes for holding and revolving parts that require extreme accuracy in the location of holes, etc. The spindle revolves in a bearing or "quill rest," which, in turn, is mounted on the bench-lathe bed in front of the headstock. The work may be held either in a "chuck quill" or be attached to a "faceplate quill"; special fixtures are also attached to the end of the quill spindle.

The *quill driver* is a special coupling used for driving a bench-lathe quill so that any jar that may be imparted to the lathe spindle by the belt joint as it passes over the cone pulley is not transmitted to the quill spindle.

Quill Punches. Piercing punches of the type shown at *A* and *B* are called "quill" punches and are used where a large

amount of stock is to be pierced or when the stock is thick in proportion to the diameter of the punch. The piercing punch is held in position by the quill or punch-holder which is driven tightly into the punch-plate. The piercing punch is slightly driven into the holder and is made of drill rod, so that it can very readily be replaced in case it is broken. The upper end of punch *A* is riveted over as shown. The holder shown at *B* is equipped with a backing screw for the punch so that the latter can be adjusted vertically. The punch is retained by a set-screw.



Quill Punches

Another method of guiding and steadying a slender punch, which is sometimes employed, consists in using straight drill rod for the punch which is supported at its lower end by the stripper plate attached to the die. Instead of making the punch straight throughout its length, it is good practice to use drill rod of standard size and then turn down the lower end for a length of about ¼ inch and to the diameter of the hole to be pierced. This allows the body part of the punch to be well entered into the stripper plate, in which it should be a close fit, before the piercing operation begins, so that the punch is rigidly supported when at work. The body of the punch should be a driving fit into the punch-plate and be riveted over at the upper end and filed flush. When made in this way, the punch will be rigid, even though it is used for piercing small holes, and, if it is well supported in the stripper plate, a much smaller punch can be employed than would be possible otherwise. When piercing heavy stock, it is well to insert a hardened steel disk in the punch-holder just above each piercing punch. This disk prevents the end of the punch from compressing the metal and thus working a depression into it, which would allow the punch to slide up and down at each stroke of the press.

Quinquevalent. Quinquevalent, also known as *pentavalent,* is a term used to indicate that an atom of one element will combine with five atoms of another element.

R

Rabbeted Joint. The rabbeted joint for the corners of patterns, boxes, etc., differs from a plain butted joint in that one corner piece is rabbeted to form a shoulder for supporting the other corner piece against inward thrusts. See Joint Used in Patternmaking.

Race. The race of a ball bearing is the groove in which the balls roll; the term is also applied to the part in which this groove is cut. The "inner race" is the part mounted on the shaft, and the "outer race" is the part surrounding the balls and mounted in the supporting structure.

Rack. A rack may be defined as a spur gear having a radius of infinite length, the pitch-line of a rack being straight. Racks are commonly used to transmit from a rotating pinion, linear motion to a machine table, slide or other part. In the involute system of gear teeth, the sides of an unmodified rack tooth are straight and inclined from the vertical to the same angle as the pressure angle. The basic rack of the standard 14½-degree composite system (full depth tooth) has a straight mid-section and cycloidal curves above and below.

Rack, Basic for Standard Gear Teeth. See Gear Tooth Standards.

Rack Cutting. Rack teeth may be cut by milling with a formed cutter, by planing with a formed tool or by a generating method. When the milling process is employed, the rack teeth are produced either by feeding a formed cutter across the rack blank or by causing the rack to feed past the cutter. After milling each tooth space, either the rack or the cutter is indexed an amount equal to the linear pitch of the rack teeth (or circular pitch of the mating pinion) except when two or more finishing cutters are used.

Rack-cutting Attachment: This attachment for a milling machine has a horizontal cutter spindle which normally is at right angles to the machine spindle. This cutter spindle is so mounted in the body of the attachment that the cutter may be traversed across the work without interference between the work and the attachment. The spindle is driven from the main spindle of the machine through suitable gearing, and the rack teeth are formed by cutting spaces straight across the blank; after each tooth space is milled, the machine table and work is indexed for cutting the next tooth space.

Generating Method: A rack can be designed, for any system of interchangeable gearing, which will mesh correctly with a range of gear sizes of the same pitch. Moreover, all gears that will mesh properly with the rack will also mesh with one another. Gear-cutting processes of the generating class are based on this interchangeable feature. In generating the teeth of spur gears, the cutter represents either a rack or a gear of the interchangeable series, and it cuts or generates teeth as the uncut gear blank and cutter are given movements, relative to each other, similar to a finished gear running in mesh either with a rack or with another gear.

Rack teeth can be generated merely by reversing this gear-cutting process. When this method is employed in connection with a gear shaper, the cutter is a circular or gear-shaped form and the rack teeth are generated as the rack moves longitudinally past the cutter which rotates slowly the same as if it were in mesh with the rack. As the cutter rotates, it also has a reciprocating motion for traversing it across the rack. The design of the Fellows rack shaper is based upon this principle.

Radial Bearing. A radial bearing, also known as a journal bearing, is a support for a shaft or axle, in which the load acts at right angles to the axis of the shaft. This term is used in contradistinction to thrust bearing, in which the load acts parallel to the axis of the shaft. A *radial ball bearing* is a ball bearing in which the bearing with its balls surrounds a shaft, and the load, acting at right angles to the shaft, is transmitted through the balls.

Radial Drilling Machine. A radial drilling machine differs from the regular upright machine in that the drilling head is mounted upon a radial arm adjustable vertically and also horizontally by swinging the arm about its supporting column. The drilling head may also be moved along this radial arm, to the required position for drilling, instead of adjusting the work or table each time a new hole is to be drilled. Because of this feature, the radial drilling machine is especially adapted to heavy work, as a number of holes can be drilled by simply adjusting the drill head to the proper position. A drilling machine known as a *post* or *wall radial type* is, in principle, constructed along the same lines as a plain radial drilling machine, but, instead of being provided with a base, it is arranged to be attached to a wall or post.

Radian. A radian is the unit of measurement of angles in what is termed "circular measure." In practical work, angles are always measured in degrees and minutes, but, in theoretical investigations and in formulas relating to revolving bodies, circu-

lar measure is often employed. A radian is the angle at the center of a circle which embraces an arc equal in length to the length of the radius of the circle. The value of a radian in degrees equals $180 \div \pi = 57.2958$ degrees. In circular measure, π denotes an angle of 180 degrees, and $\pi \div 2$, an angle of 90 degrees. It is especially convenient to measure angles in radians when dealing with angular velocity, because, in this case, a very simple relationship is obtained between angular velocity, linear velocity, and the radius of the revolving body. This is the reason for using the radian as a unit of angular measurement. If $\omega =$ angular velocity per second of revolving body, in radians, $v =$ velocity of a point on the periphery of a body, in feet per second; $r =$ the radius, in feet; then $\omega = v \div r$.

Radiant Heat. See Heat and Heat Transfer.

Radical in Chemistry. A radical is a group of atoms which remains unchanged during a series of chemical reaction, and hence may be regarded as replaceable by a single atom.

Radical in Mathematics. A radical is an expression indicating a root, as $\sqrt{5}$. The "radical sign" is the root sign ($\sqrt{\ }$).

Radio Frequency. A radio frequency is a frequency usually higher than those frequencies corresponding to normally audible sound waves and lower than those corresponding to heat and light waves. Roughly, the practicable limits of radio frequency extend from 10 kilocycles per second to 2000 megacycles per second.

Radiography. Radiography is the use of x-ray equipment to inspect the soundness of welds and castings.

Radium. Radium is a metallic chemical element, the symbol of which is Ra, and the atomic weight, 226.4. Radium is a rare metal found only in small quantities and commanding a very high price. It is one of the most remarkable of all metals. It emits light rays which like the X-rays are invisible, but which traverse sheets of glass or metal and cannot be refracted. Radium emits three kinds of rays, which for convenience are called alpha, beta, and gamma rays. Of these, the gamma rays, which greatly resemble the Roentgen or X-rays, have tremendous penetrating power.

Radius of Gyration. The center of gyration with reference to an axis is the point at which the entire mass of a body may be considered as concentrated, the moment of inertia, meanwhile, remaining unchanged; or, in a revolving body, the center of gyration is the point at which the whole mass of the body may be considered as concentrated, the angular velocity remaining the

same. The *radius of gyration* is the distance from this point to the axis of rotation. If W is the weight of a body; I, its moment of inertia; and k, the radius of gyration, $g = 32.16$, then:

$$k = \sqrt{\frac{Ig}{W}} \text{ and } I = \frac{Wk^2}{g}$$

To find the radius of gyration of an area, such as the cross-section of a beam, divide the moment of inertia of the area by the area, and extract the square root. The square of the radius of gyration of an oscillating body is equal to the product of the radius of oscillation multiplied by the distance of the center of gravity of the suspended body from the point of suspension. When the axis, with reference to which the radius of gyration is taken, passes through the center of gravity, the radius of gyration is the least possible and is called the *principal* radius of gyration. For a solid cylindrical body, such as a disk or emery wheel, the radius of gyration is equal to the radius of the disk divided by $\sqrt{2}$ or radius $\times$ 0.707. For a flywheel rim, it is sufficiently accurate to assume the radius of gyration to be the distance from the center to a point halfway between the outer and inner edges of the rim. Formulas for the radius of gyration for bodies of all ordinary geometrical shapes will be found in standard engineering handbooks.

Radius of Oscillation. See Center of Oscillation.

Rake of Metal-Cutting Tools. When a lathe or other metal-cutting tool is so ground that the surface against which the chips bear, while being severed, inclines in such a way as to increase the keenness of the cutting edge, it is said to have "rake." If the inclination is such as to give the tool less keenness than is equivalent to a rake angle of zero, the term *negative rake* is often used. The amount of rake or slope that a tool should have depends upon the work for which it is intended. If, for example, a turning tool is to be used for roughing medium or soft steel, it should have a back slope of about 8 degrees and a side slope ranging from 14 to 20 degrees, while a tool for cutting very hard steel should have a back slope of about 5 degrees and a side slope of 9 degrees.

Ram, Hydraulic. See Hydraulic Ram.

Rankine, Degrees. Degrees Rankine (absolute temperature scale) equal degrees Fahrenheit plus 459.69.

Rankine's Formulas. These formulas were developed for the calculation of the strength of columns. They are also known as Gordon's formulas. According to these formulas, if $S =$ the ultimate compressive strength of the material in pounds per

square inch, l = the length of the column or strut in inches, r = the least radius of gyration in inches (r^2 = moment of inertia divided by area of section), and p = the ultimate load in pounds per square inch; then for steel columns with both ends fixed:

$$p = \frac{S}{1 + \frac{l^2}{25{,}000\ r^2}},$$

and for cast-iron columns with both ends fixed

$$p = \frac{S}{1 + \frac{l^2}{5000\ r^2}}$$

For Rankine's formulas covering other conditions of columns, and Euler's formulas for slender columns, see MACHINERY'S Handbook.

Raoult's Method. This is a process for determining atomic weights based upon the discovery that the molecular weight of a compound may be determined from the changes caused in the freezing or boiling point of a liquid in which the compound is dissolved. The method can be used only with substances which have no chemical action upon the solvent.

Rapping Plates. Rapping plates for patterns are pieces of metal let in flush with the joint or cope side of the pattern and fastened with screws. They come in different shapes and sizes and are provided with a central hole that is tapped to receive the threaded end of a lifting iron. In addition to the tapped hole, there are one or more plain holes for the reception of a rapping bar. Countersunk holes are provided for fastening screws.

Rasps. A rasp is a file having teeth that are round on the top and disconnected, the teeth having been formed by raising small portions of the stock from the surface of the blank. This type of file is used for heavy, rough filing, where a considerable amount of material is to be removed, but where a smooth surface is not required. There are several different types of rasps. Their names and general features follow:

Cabinet: Flat on one side, convex on the other. Width and thickness tapered. Edges slightly blunted and cut.

Horse, Plain: No tang. Rasp cut on one side, file cut on the other.

Horse, Tanged: Similar to horse, plain, but with tang.

Shoe, Flat: Section uniform throughout. One half of each face cut with rasp teeth, the other half with file teeth.

Shoe, Half-round: Flat on one side, convex on the other. Otherwise, similar to flat shoe rasp.

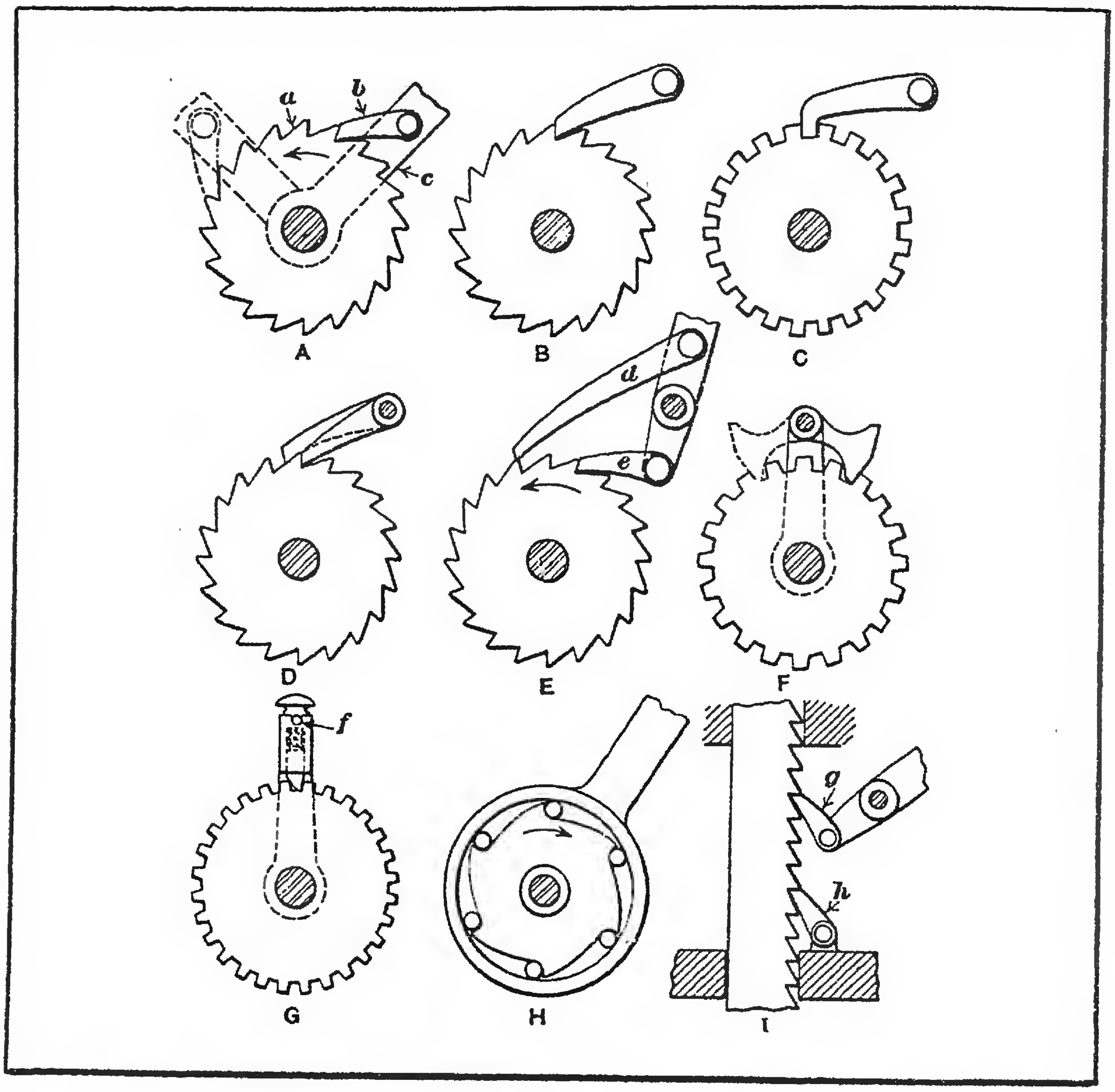
Wood, Flat: Width and thickness tapered.
Wood, Half-round: Similar to cabinet rasp, but coarser.

Ratchet Drills. The ratchet drill is a hand-operated tool and is generally applied to work which cannot be taken to a drilling machine. For instance, ratchet drills are often used for drilling holes in boilers, frames, bed-plates, or other heavy machine parts, especially in connection with the erection or repair of machinery and when a power-driven portable drilling machine is not available or cannot be used for lack of room. It is necessary to provide a support for the feed-screw end of the ratchet so that the drill can be forced into the metal as it is turned by a ratchet lever. In many cases, a part of the machine may be used for this purpose. If there is no rigid backing for the ratchet, the usual method is to clamp or bolt a brace or "old man" near the point where the hole is to be drilled. This brace has an adjustable arm which is clamped at the proper height, and the conical point of the ratchet feed-screw is engaged with one of the numerous center holes which are usually formed on the lower side of the arm. Some ratchet drills are designed to rotate the drill in one direction only, whereas others are reversible.

Ratchet Gearing. Ratchet gearing in its simplest form consists of a toothed ratchet wheel *a* (see diagram *A*), and a pawl or detent *b*, and it may be used to transmit intermittent motion or to prevent relative motion between two parts except in one direction. The pawl *b* is pivoted to lever *c* which, when given an oscillating movement, imparts an intermittent rotary movement to ratchet wheel *a*. Diagram *B* illustrates another application of the ordinary ratchet and pawl mechanism. In this instance, the pawl is pivoted to a stationary member and its only function is to prevent the ratchet wheel from rotating backward. With the stationary design, illustrated at *C*, the pawl prevents the ratchet wheel from rotating in either direction, so long as it is in engagement with the wheel. The principle of the *multiple-pawl ratchet gearing* is illustrated at *D*, which illustrates the use of two pawls. As will be seen, one of these pawls is longer than the other, by an amount equal to one-half the pitch of the ratchet-wheel teeth, so that the practical effect is that of reducing the pitch one-half. By placing a number of driving pawls side by side and proportioning their lengths according to the pitch of the teeth, a very fine feed can be obtained with a ratchet wheel of comparatively coarse pitch.

The type of ratchet gearing shown at *E* is sometimes employed to impart a rotary movement to the ratchet wheel for both the forward and backward motions of the lever to which the two pawls are attached. A simple form of *reversing ratchet* is illus-

trated at *F*. The teeth of the wheel are so shaped that either side may be used for driving by simply changing the position of the double-ended pawl, as indicated by the full and dotted lines. Another form of reversible ratchet gearing for shapers is illustrated at *G*. The pawl, in this case, instead of being a pivoted latch, is in the form of a plunger which is free to move in the direction of its axis, but is normally held into engagement with the ratchet



Different Forms of Ratchet Gearing

wheel by a small spring. When the pawl is lifted and turned one-half revolution, the driving face then engages the opposite sides of the teeth and the ratchet wheel is given an intermittent rotary motion in the opposite direction.

The *frictional type* of ratchet gearing differs from the designs previously referred to, in that there is no positive engagement between the driving and driven members of the ratchet mechanism, the motion being transmitted by frictional resistance. One

type of frictional ratchet gearing is illustrated at *H*. Rollers or balls are placed between the ratchet wheel and an outer ring which, when turned in one direction, causes the rollers or balls to wedge between the wheel and ring as they move up the inclined edges of the teeth. Diagram *I* illustrates one method of utilizing ratchet gearing for moving the driven member in a straight line, as in the case of a lifting jack. The pawl *g* is pivoted to the operating lever of the jack and does the lifting, whereas the pawl *h* holds the load while the lifting pawl *g* is being returned preparatory to another lifting movement.

Rate of Combustion for Boilers. The weight of coal burned in a boiler, per square foot of grate surface per hour is called the *rate of combustion.* This rate commonly varies from 12 to 25 pounds in the case of power plants operating under natural draft, increasing to 30 pounds or more when forced draft is employed. With heating boilers, the combustion is somewhat less, as it is unusual to force the boilers so much, except in large plants. Here the rate drops to 8 or 10 pounds in boilers of medium size, and to 6 or 7 in those of small size, depending upon the care they receive and the strength of chimney draft.

Rate of Evaporation. The weight of dry steam evaporated in a boiler per pound of coal is called the *rate of evaporation.* This rate varies with the character of the heating surface and its relation to the grate area. In power boilers of good design, the rate of evaporation generally varies from 9 to 10 pounds, while in the case of heating boilers, it is more commonly 7 or 8 pounds.

Ratio. The *ratio* between two quantities is the quotient obtained by dividing the first quantity by the second. For example, the ratio between 3 and 12 is ¼, and the ratio between 12 and 3 is 4. Ratio is generally indicated by the sign (:); thus 12 : 3 indicates the ratio 12 to 3. A *reciprocal* or *inverse* ratio is the reciprocal of the original ratio. Thus, the inverse ratio of 5 : 7 is 7 : 5.

Ratio of Expansion. The ratio of expansion in a steam engine cylinder is the reciprocal of the cut-off, that is, if the cut-off is ¼, the ratio of expansion is 4. In other words, it is the ratio of the final volume of the steam at the end of the stroke to its volume at the point of cut-off. For example, a cylinder takes steam at boiler pressure until the piston has moved one-fourth the length of its stroke; the valve now closes and expansion takes place until the stroke is completed. The one-fourth cylinderful of steam has expanded to four times its original volume, and the ratio of expansion is said to be 4.

The most economical ratio of expansion depends largely upon the type of the engine. In the case of simple engines, the ratio is limited to 4 or 5, on account of excessive cylinder condensation in case of larger ratios. This limits the initial pressure to an average of about 90 pounds for engines of this type. In the case of compound engines, a ratio of from 8 to 10 is commonly employed to advantage, while, with triple-expansion engines, ratios of 12 to 15 have given good results.

Ratio of Slenderness. In the calculation of columns an expression "ratio of slenderness" is frequently used. This ratio is obtained by dividing the length of the column by the radius of gyration, and is simply a number which indicates the length of a column as compared with the important dimensions based upon its cross-section. The ratio of slenderness determines evidently to a considerable extent the load to which a column may be subjected. This load also depends to a large extent upon whether the ends of the column are fixed or hinged.

Ratios, Speed-Changing Mechanisms. See under Speed-changing Mechanisms.

Reactance. When alternating current flows in a circuit composed of elements having either inductance or capacity (theoretically, all elements have both, if only in a minute degree), there is set up an opposition to the flow of current, in addition to that provided by any resistance therein, which has been given the name of reactance. The amount of reactance depends upon the amounts of inductance and capacity in the circuit or element and also is a function of the current frequency. It is measured in ohms, the same as resistance, and is equal to the component of the impressed electromotive force at right angles to the current divided by the current.

Inductive reactance, such as that provided by a wire coil, is opposite in effect to capacitive reactance, such as that provided by a condenser, in that the former causes a current to lag behind the voltage producing it, while the latter causes the current to lead the voltage which produces it. Both inductive and capacitive reactance are in quadrature with resistance.

Reactance Coils. Reactance coils are designed to have a high amount of inductive reactance for a given frequency range and thus tend to limit the flow of alternating current through them at such frequencies. Reactance coils are used in power systems to limit the flow of current in case of short circuit while the damaged part is being isolated. They are used extensively in telephone and radio circuits as choke and filter coils in association with resistances and condensers. When so used, they prevent the passage of unwanted currents at certain frequencies while

permitting the passage of other currents at desired frequencies. This is possible because the reactive values of both coils and condensers vary with the frequency, and they may be combined in such a way as to offer little or no reactance at certain frequencies, while, at the same time, offering extremely high reactance to other frequencies.

Reading Mechanical Drawings. The expression "reading a drawing" simply means obtaining a clear understanding of it, by referring to the different views. Experienced draftsmen, machinists, toolmakers, and patternmakers are all able to read drawings, although it does not follow that they could make a suitable drawing. Everyone can understand an ordinary perspective drawing, because it represents the object as it would actually appear to the eye, but a mechanical drawing with its different views, numerous full and dotted lines, dimensions, symbols or abbreviations is comparatively complex, although it shows to the trained eye a great deal more than would be possible, in most cases, by a perspective drawing. The first step in learning how to read drawings is to study elementary mechanical drawing principles; the use of different views for representing different sides of a mechanical device and the use of other features common to mechanical drawings, such as dotted lines to represent concealed parts, sections, and the meaning of certain abbreviations. The best plan is to begin with simple drawings and then practice reading more complex ones, securing as great a variety as possible. In reading a drawing, it is advisable to visualize the object as far as possible, or see it in the mind's eye as it would appear when constructed. This is where the imagination comes into play and also the ability to grasp readily the relation between the different views by glancing from one view to the other. For instance, if there are front, plan, and side views, these separate views on the drawing are combined mentally so that the mental picture corresponds to that of the object.

Reagent. A reagent, in chemistry, is any substance which is used to effect a chemical change in another substance for the purpose of chemical analysis.

Realgar. Realgar is a compound of arsenic and sulphur (chemical formula, As_2S_2). It occurs in nature in prismatic crystals and has a specific gravity of 3.5. It is prepared artificially by fusing together arsenic and sulphur, but the resulting product varies somewhat in composition.

Reamer. Reamers are used for two purposes: (1) for producing a hole that is smooth and true to size, and (2) for enlarging cored or drilled holes. With reference to the manner in which reamers are made, they may be divided into solid and in-

serted-blade reamers, the latter usually being adjustable for size. *Hand reamers* include straight reamers intended to be used by hand for producing holes that are smooth and true to size. *Fluted chucking reamers* are used in machines for enlarging holes and finishing them smooth and true to size. *Rose chucking reamers* are used in machines for enlarging cored holes and are so constructed that they are able to remove a considerable amount of metal. *Shell reamers* are provided with a hole through the center in order to save the material which otherwise would be used for the reamer shank, and are mounted by means of this hole on arbors. Shell reamers may be either of the fluted chucking or the rose chucking reamer type. *Taper reamers* are used for reaming the holes for standard taper sockets, standard taper pins, and, in general, tapered holes that must be true as regards size and taper. *Pipe reamers* constitute a large class of taper reamers; they are used for reaming taper holes previous to tapping the taper pipe taps. *Center reamers* are used for reaming the center holes in work that is to be held between the centers in different types of machine tools. *Jobbers' reamers* are similar to hand reamers and are used for similar purposes, but are provided with a taper shank so that they may be used in machines. *Taper bridge reamers* are a special type of reamers used for reaming rivet holes in structural construction work. *Grooved chucking reamers* are used for enlarging cored holes. They are fluted with spiral grooves like a twist drill and may be said to occupy a place on the boundary between reamers and drills.

Reamers used on cast iron and steel usually are fluted so that the teeth are either radial or slightly ahead of the center. If the faces of the teeth are ahead of the center, this provides negative rake, which is desirable for reamers used on brass work.

Reamer Clearance. A reamer having proper clearance cuts freely and smoothly. There are three kinds of clearance, which may be described in the following order: 1. Longitudinal, which nearly all reamers should have to some extent. This is a slight taper which makes the reamer smaller toward the shank in order to prevent the back end from enlarging the hole or dragging and thereby roughing up the hole. 2. The clearance on the entering end of the teeth which every reamer ought to have. 3. The clearance along the sides of the teeth or on the peripheral part of the reamer. The latter is sometimes called radial clearance or relief.

Reamer Teeth Spacing. There are three methods of spacing reamer teeth. First, they may be spaced evenly around the entire surface; second, the spacing may be irregular but with one half of the circumference corresponding to the other half, so that the cutting edges are diametrically opposite; and third, the spacing may be irregular around the entire circumference. The object

of uneven spacing is to eliminate chatter and produce smoother holes than are obtained with uniformly spaced teeth. Some contend that a reamer spaced according to the second method is liable to chatter and that no two cutting edges should be diametrically opposite.

It is undoubtedly true that an odd number of teeth in a reamer favors smoother work than an even number of equally spaced teeth. The reason for this is as follows: In a reamer having an even number of teeth, any ridge or hard spot in the work tends to push the tooth away at that point and the action is transmitted diametrically across the reamer to the opposite side of the hole. If the reamer has an odd number of teeth, the effect is transmitted across the hole to two teeth instead of one and is, therefore, less than if concentrated on one tooth. In other words, the irregularities are not see-sawed back and forth across the hole by the action of the teeth as much with an uneven number of teeth as with an even number. The average manufacturer, however, prefers reamers with an even number of teeth because of the difficulty of measuring those with an odd number of teeth. Reamers that have an even number of teeth, but with the spacing broken up so that it is irregular, can be made to ream a hole as true as an odd-toothed reamer.

Reaumur Thermometer. The thermometer which is most commonly used for general purposes in Germany and other German speaking countries is the Reaumur thermometer, introduced about 1730 by the French scientist Reaumur. On the Reaumur scale, the freezing point of water is located at 0, and the boiling point of water, at atmospheric pressure, at 80 degrees. The following formulas may be used for converting temperatures given on the Reaumur scale to temperatures on the Centigrade and Fahrenheit scales:

$$\text{Degrees Reaumur} = \frac{4 \times \text{degrees C.}}{5}.$$

$$\text{Degrees Reaumur} = \frac{4 \times (\text{degrees F.} - 32)}{9}.$$

For scientific work the Centigrade scale is used almost exclusively in all countries.

Recalescence Point. The recalescence point, sometimes designated Ar. 1, is the temperature at which the internal structure of steel which has been heated above the decalescence point and then allowed to cool slowly, changes back to the structural condition existing before the steel was heated above the decalescence point. When a piece of steel has been heated above the hardening temperature and is permitted to cool slowly, its temperature falls uniformly until the recalescence point is reached, but here the

internal changes of the carbon and iron that take place evolve a certain amount of heat, so that the temperature remains stationary for a short time, and sometimes even rises slightly. After the internal changes have taken place, the steel will continue to cool off gradually. The recalescence point for different kinds of steel varies, but is about from 1325 to 1400 degrees F.

Recarburizing. Recarburizing is the process of adding carbon to the charge in a Bessemer converter. The usual recarburizers are ferro-manganese, spiegeleisen, ferro-silicon, and silico-spiegel.

Receiver, Air. See Air Receiver.

Recessing Tool. A recessing tool is a cutting tool intended for cutting an internal groove or recess in a machine part. Recesses are often cut on the inside of castings and forgings in places which may be rather inaccessible. Special tool-holders and devices, all of which are generally classified as "recessing tools," are sometimes used for this purpose.

Rectifier. Rectifiers are devices which are so designed as to permit an appreciable flow of current through them in one direction only. They are used for the purpose of rectifying alternating current, i.e., changing it into direct current. For supplying power in any quantity, some form of mercury rectifier is generally used. The mercury arc type consists of a tube containing mercury vapor under low pressure, together with a pool of mercury which acts as a cold cathode and an anode usually of graphite. Operation of the rectifier is based on the observed fact that the passage of current from the anode to the cathode may be easily effected, but high resistance is offered to the passage of current in the opposite direction. A different type of mercury rectifier with a hot cathode is known as the "Phanatron," while a third type has a grid in addition to the hot cathode and this is called a "Thyratron." This latter type may be used to rectify alternating current at any frequency or for converting the frequency of alternating current or for converting direct current into alternating current. Considerable attention has been given to developing the use of the Thyratron rectifier for supplying direct current for long distance transmission at high voltages.

There are several other types of rectifiers which are used where power requirements are small. The Tungar rectifier, which consists essentially of a two-element electronic tube, is one of these. The so-called disc type of rectifier utilizes copper oxide, copper sulphide, or some similar type of coated disc which offers a high resistance to the passage of current in one direction but not in the other. Certain electrolytes and crystals have similar properties, but their current-carrying capacities are usually small.

Rectilinear Crane. This is a crane in which the load is first moved in a straight line in one direction and then in a straight line in a direction at right angles to the first. The over-head traveling crane is an example of this type. Some rectilinear cranes are provided with movement for the load in one direction only.

Red Brass. The alloy known as "red brass," contains 85 per cent of copper, 5 per cent of tin, 5 per cent of lead, and 5 per cent of zinc. This is the recognized standard red brass. There are numerous modifications, for various purposes. A metal used widely for pump bodies, valves, and similar parts, known as *red composition* or *ounce metal* has the same composition as red brass. For general service, this is regarded as an excellent bearing metal.

Red Hardness. A term sometimes applied in connection with high-speed steel because of its property of retaining a sufficient hardness for cutting metals even when heated to a temperature high enough to cause dull redness. The property of red hardness is conferred upon the steel by the presence of tungsten and by the heat-treatment to which it is subjected. See High-speed Steel.

Red Hematite Ore. See Hematite Ore.

Red Lead. Red lead is a bright red pigment made either by oxidizing litharge in furnaces or by heating it with sodium nitrate in iron pots. The color varies somewhat according to the conditions of manufacture and other details. It is widely used for the protection of iron, and is considered to be one of the best pigments known. It is generally mixed with oil, when required for use, in the proportion of 30 pounds of pigment to a gallon of oil. It exerts such a drying action on the oil that no other drier is necessary. Sulphurous gases tend to turn it brown, and it is often mixed with certain inert materials.

Reducer. Reducers may be classified as follows: (1) A fitting having a larger size at one end than at the other. Some have tried to establish the term "increaser"—thinking of direction of flow—but this has been due to a misunderstanding of the trade custom of always giving the largest size of run of a fitting first; hence, all fittings having more than one size are reducers. They are always threaded inside, unless specified flanged or for some special joint. (2) Threaded type, made with abrupt reduction. (3) Flanged pattern with taper body. (4) Flanged eccentric pattern with taper body, but flanges at 90 degrees to one side of body. The term reducer is misapplied at times to a reducing coupling.

Reducing Agent. The term is applied to a substance that removes oxygen or elements similar to it. See Oxidizing and Reducing Agents.

Reducing Presses. Reducing presses are used for reducing in diameter cups or shells previously cut and formed in double-action presses, in order to form tubes which may vary more or less in length. Reducing presses are used more especially in the manufacture of such articles as cartridges, ferrules, pencil tubes, pencil cases, pen holders, burner tubes, and large variety of other articles made of brass and silverware. These presses are also extensively used for forming, bending, and finishing operations on deep work. They are built in different types and sizes and, in some cases, have automatic dial feeding mechanisms.

Reduction of Area. See Elongation and Reduction of Area.

Reference Gages. Reference gages are made to test or check the dimensions of inspection gages. The tendency is toward reducing the cost of gaging systems by making reference gages only when standard measuring plugs or other simple and accurate measuring means cannot be conveniently used. When a comparatively small number of pieces are to be made, it is also more economical not to make reference gages. When the inspection gages and working gages are made to different tolerances, reference gages are not provided for the working gages, due to the fact that it would require a separate set of reference gages, which is unnecessary and which would merely involve an additional expense.

Reference gages are generally made the reverse or opposite to the inspection gages; that is, female reference gages are made for male inspection gages, and vice versa. As a rule, it is best to make the reference gages so that they fit the gaging and locating surfaces of the inspection gage to the same extent that the work fits the inspection gage. In this way, wear of the gage is more easily detected. It is not customary, however, to make a ring gage as a reference gage for a plug inspection gage, but a snap gage is used instead. The reference gage for a snap inspection gage, again, is usually a cylindrical plug gage, not a flat plug gage. By a flat plug gage is meant a plug gage that is rectangular in cross-section.

While it is the general practice to make reference gages opposite to the inspection gages, this is not always the case. It is, for example, most convenient to compare a plug gage with another plug gage, and this holds true especially with thread gages, because it is much easier to compare the diameters of a plug thread gage with another plug thread gage than to do the checking with a ring gage.

While a reference gage for a snap gage will have both maximum and minimum limits, the general practice is to make only one reference gage for contour gages, flush-pin gages, and similar types, in order to minimize the expense. The reference gage in that case ought to be made to correspond to the basic, or, generally speaking, to the maximum metal dimension on the drawing of the component part for which the gages are used.

Refractory. A refractory is a high-melting-point material used to make furnace linings or kilns.

Regenerative Braking. When regenerative braking is used on an electric motor (either direct- or alternating-current), the motor is connected for the desired direction of rotation as a separately excited generator to a constant voltage supply system, and if the machinery to which the motor is connected attempts to drive it at greater than full speed, it will generate electric power and supply it to the power system in the same way as a central station generator would do. This regenerative electric power causes the motor to produce a holding back or braking effect on the machinery to which it is connected. See Dynamic Braking.

Regular Lay. This term indicates the direction of twist in wire ropes. In ropes having regular lay, the wires of the strands are twisted in one direction and the strands are laid into the rope in the opposite direction. This type of rope, in the United States, at least, may be considered as the standard.

Regulating Pole Converter. This is a synchronous converter used for producing a variable direct-current voltage. The regulating pole converter differs from the ordinary converter in that the field poles are divided into two parts, a main pole and a regulating pole. The ratio between the direct- and the alternating-current voltages may be changed by varying the excitation of the regulating poles by using a field rheostat for controlling the exciting current. It is sometimes called a split-pole converter.

Reheader. A reheader is a cold-heading machine in which pieces that have been partly formed in an ordinary heading machine are completed. By means of an automatic hopper feed, the pieces are placed in the heading dies and the subsequent operations performed.

Reinforced Concrete. Reinforced concrete consists of concrete in which steel bars of various forms, or special forms of steel wire mesh are imbedded. The object is to make concrete able to resist tensile stresses as well as compressive stresses. The steel bars are usually fixed at the ends by being built into columns, walls, etc., and should preferably be continuous from the immediate supports.

Relative Velocity. The rate of motion of a body with relation to another moving body is the relative velocity, the term being used to distinguish between relative and absolute velocity, the latter being the velocity of a body with reference to some object which is considered completely at rest. The piston of a locomotive cylinder has a relative velocity with reference to the cylinder walls, but its absolute velocity is its rate of motion with reference to the rails and equals that of the train plus or minus the relative velocity of the piston with reference to the cylinder, the relative velocity being added to the train velocity when the piston moves in the direction of the train, and subtracted from the train velocity when the piston moves opposite to the motion of the train.

Relays. For the most part, relays may be considered to be specialized types of remote control switches for opening and closing electrical circuits. A few types are, however, designed to perform some simple mechanical function such as counting, sorting, measuring, etc. By far, the majority of relays in use are of the electromagnetic type wherein the moving arm, or armature, which performs the switching operation is actuated by an electromagnet. In the so-called clapper type, the armature is hinged at one end and moves to and from the face of the magnet core. In the solenoid type, the armature is moved back and forth inside the magnet coil. Variations in design provide for contact closure in a vacuum sealed tube, mercury contact, as well as the regular open-air contacts of special alloys which resist pitting and "freezing." In some low-voltage types, 200 or more circuits may be controlled by a single relay.

One important type of relay provides for actuation after a given time delay. Synchronous motors, clock mechanisms, gas chambers with bleeder valves, condenser-charging and thermal elements are all used as a means of controlling the time of operation.

Thermostats are special types of relays which are actuated by heat to open or close a circuit. Photo-electric relays are similarly actuated by light and acoustic relays by sound. Certain electronic tubes are also used as very sensitive relays.

Relays are widely used for the protection of motors against overload, overheating and excessive speed. Their widest use is for signalling and communication circuit control. One recent application of interest is the control of artificial light in accordance with the intensity of sunlight entering a room or building interior. They may be used in connection with the automatic tripping of circuit-breakers or oil switches when predetermined abnormal conditions occur. Oil switches and air-break circuit-breakers that are tripped automatically are provided with alternating- or direct-current trip coils to which the contacts of the

relay may be electrically connected, or with tripping mechanisms on which the movable part of the relay may act directly. As so used, their usual purpose is to assist in disconnecting that part of an electrical system in which a fault has occurred, from the rest of the system, with the least practicable delay; and to limit such disconnecting to that part of the system that is in trouble.

Relief of Taps. A tap is said to be relieved when the portions of the land back of the cutting edge are so cut away that the heel of the land is nearer to the axis of the tap than is the cutting edge. The object of this relief is to enable the tap to cut more freely, by giving it a keener cutting edge, and by reducing to a minimum the friction between the teeth of the tap and the work being tapped. It is apparent that taps may be relieved both on the outside diameter and in the angle (and then also at the root) of the thread, or they may be relieved only on the top of the thread, but not in the angle (or at the root) of the thread. A number of different methods have been used for relieving straight or non-tapering taps. In many instances, no relief at all has been given to the full threads, but the tops of the threads of the chamfered portion at the end of the tap have been relieved in a manner similar to that used for milling cutters. In other instances, the thread has been relieved both on the top and in the angle, clear from the cutting edge to the heel.

The method of relieving the tap both on the top and in the angle of the thread clear from the cutting edge to the heel has the objection that the tap will lose its size as soon as it is ground on the face of the cutting edge which is the correct method of sharpening. Furthermore, it is claimed that taps thus relieved cannot cut a perfectly round and smooth hole, because they are not sufficiently supported while cutting, as the surface of contact between the tap and the work is practically limited to a number of points. To overcome the objection of having only point supports, taps have been manufactured with relief in the angle of the thread only, while the outside was left the full diameter of the thread from the cutting edge to the heel.

On account of the many objections to the various kinds of relief on straight-threaded taps, most manufacturers have adopted the practice of providing their taps with "back taper"; that is, the diameter of the thread both in the angle and on the outside is made a very small amount less at the end of the thread joining the shank than at the point. When taps are made in this way, the cutting size of the tap will be at the large end of the chamfered portion. At the shank end of the thread, the diameter will be anywhere from 0.0005 to 0.0025 inch smaller than at the point, according to the size of the tap.

Relieving. Relieving, also known as *backing off*, is the process of removing, by turning, grinding, or milling, some of the metal behind the cutting edge of a cutting tool in order to provide clearance; applied specifically to milling cutters, taps, dies, reamers, and drills. Many milling cutters for gear cutting and form milling are so relieved that the cutting edges retain the same shape or curvature, as the front faces of the teeth are ground repeatedly for sharpening.

Relieving Attachments. A relieving attachment is a device applied to lathes (especially those used in tool-rooms) for imparting a reciprocating motion to the tool-slide and tool, in order to provide relief or clearance for the cutting edges of milling cutters, taps, hobs, etc. For example, in making a milling cutter of the formed type, such as is used for cutting gears, it is essential to provide clearance for the teeth and so form them that they may be ground repeatedly without changing the contour or shape of the cutting edge. This may be accomplished by using a relieving attachment. The tool for "backing off" or giving clearance to the teeth corresponds to the shape required, and it is given a certain amount of reciprocating movement, so that it forms a surface back of each cutting edge, which is of uniform cross-section on a radial plane but eccentric to the axis of the cutter sufficiently to provide the necessary clearance for the cutting edges.

Reluctance. When a material is subjected to a magnetomotive force, its reluctance is that property which opposes the establishment of magnetic flux and in this respect is analogous to resistance which tends to oppose the flow of electric current. Thus, in a simple closed magnetic circuit, it can be said that reluctance is equal to magnetomotive force in that circuit divided by flux. Since unvarying flux is thought of as a static condition, one should not think of reluctance as producing an energy loss, however, as does resistance. In a magnetic material, the reluctance is not a constant quantity, since it is a function of permeability which varies with magnetizing force and flux density.

The unit of reluctance (which used to be the oersted but to which no name is now assigned) is the reluctance offered by a portion of a magnetic circuit 1 centimeter long by 1 square centimeter in cross-section, and of unit permeability. The reciprocal of reluctance is *permeance.*

Repeated-Stress Tests. With the repeated-stress method of testing, a test specimen is held firmly, and a load not sufficient to rupture it is applied, released, and applied again, this procedure being rapidly repeated a large number of times; or the specimen may be strained in one direction, released, and strained

in the opposite direction, then released again and strained in the first direction, this procedure being repeated a great number of times. A record is made of the method of loading and the number of alternations necessary to cause breakage or, as it is commonly termed, "failure." The object of repeated-stress tests is to determine as nearly as possible the probable action or life of a given material under assumed working conditions. The methods used vary greatly.

Replacement Value. The replacement value of a machine or other unit is the actual cost of replacing the unit with one of the same type, at prevailing market prices at the time of appraisal. Replacement value, then, is the market price with freight and cost of installation added. In the case of large machine tools, the freight and installation items are large enough to be well worth considering, especially when expensive foundations are necessary. In appraising medium-size machinery, an allowance of five per cent of the market price of the machine is made to cover freight and ten per cent to cover installation. In appraising small parts of machinery and small tools, these items are practically negligible when considering individual tools. Of course, in appraising the contents of a tool-room, where large quantities of tools have been purchased in bulk, some allowance should be made for freight.

Resinoid Wheel. A resinoid wheel is a grinding wheel made of bonded synthetic resin.

Resistance. Resistance is the property of a substance that opposes the flow of an electric current. For a given current, it determines the rate at which electrical energy is converted into heat or radiant energy. The electrical resistance of a homogeneous conductor varies directly with its length, and, inversely with its cross-sectional area. For metal conductors, it also increases with the temperature. The "specific resistance" is the resistance per mil-foot of a material; it is also sometimes termed "resistivity." The practical unit of resistance is the ohm. According to Ohm's law, in a circuit in which continuous current is flowing, the resistance in ohms is equal to the electromotive force (or potential difference) in volts divided by the current in amperes.

Resistance, Air. See Air Resistance.

Resistance Materials, Electrical. Materials which offer a high resistance to the flow of electric current are used for two purposes: (1) For the reduction of current flow and (2) for the production of heat. For current control, copper or carbon is commonly used, although other materials such as iron and silicon carbide find specialized applications. For the production of heat, pure iron, nickel, or some form of nickel alloy contain-

ing chromium, copper, iron, manganese as additional elements are generally used. The nickel-chromium alloys, such as Chromel, Nichrome and Tophet, provide high working temperatures of 1000 degrees C. or more. Copper-nickel alloys, such as Advance, Constantan, and Manganin, offer remarkably stable resistance values at widely different temperatures and are also utilized where constant resistance is needed, as, for example, in certain measuring instruments and resistance standards.

Silicon-carbide resistances in rod or tube form are used in industrial applications and have a continuous operating temperature limit of 2400 degrees F., or more. Composition resistance materials are also used in some cases where a non-inductive resistance of high value is required.

Resistance Welds, Classes. The various types of resistance welds may be described as follows:

A *lap spot weld* is a spot weld made by the spot-welding process wherein a lap joint is used.

A *bridge spot weld* is a spot weld made by the spot-welding process wherein the parts are joined by the spot welding of disks or strips across a butt joint. (Sometimes called "tie welding.")

A *button spot weld* is a spot weld made by the spot-welding process wherein the parts are joined by spot-welding disks or buttons between the overlapping joint edges.

A *disk depression weld* is a spot weld made by the spot-welding process wherein one or both of the overlapping parts to be joined is/are provided with annular grooves for the reception of disks or buttons to localize the heat.

A *projection weld* is a spot weld made by the spot-welding process wherein stamped projections to localize the heat are provided in one or both of the overlapping parts to be joined.

A *multiple projection weld* is a projection spot weld wherein the contact points cover two or more of the projections in the parts to be joined.

A *ridge projection weld* is a projection weld made by the spot-welding process wherein the parts to be welded are provided with ridges which intersect, thus localizing the heat at points.

A *multiple-electrode spot weld* is a spot weld made by the spot-welding process wherein several contact points are simultaneously operated.

A *tee spot weld* is a spot weld made by the spot-welding process wherein the parts to be welded form a tee, one of the parts being held in a hollow electrode.

A *duplex spot weld* is a spot weld made by the spot-welding process wherein two spots are welded simultaneously by the simultaneous use of two transformers on opposite sides of the sheets

to be welded, the current passing through two secondaries.

A *mash weld* is a spot weld made by the spot-welding process wherein overlapping rods, wires, strips, etc., are welded between relatively large contact points.

A *butt seam weld* is a seam weld made by the seam-welding process wherein a butt joint is used and the edges progressively welded.

A *lap seam weld* is a seam weld made by the seam-welding process wherein a lap joint is used.

A *bridge seam weld* is a seam weld made by the seam-welding process wherein a strap is welded across a butt joint.

A *tee butt weld* is a butt weld made by the resistance butt-welding process wherein flat strips, bars, etc., are welded at right angles in the form of a tee. Sometimes a portion of one piece is preheated by the welding current prior to welding.

A *jump butt weld* is a form of tee butt weld wherein one of the parts joined is relatively small compared with the part to which it is joined as, for example, in the end welding of a nail or screw to a strip or plate.

An *angle butt weld* is a butt weld made by the resistance butt-welding process wherein the parts are welded at an angle.

Resistance Welding Methods. The various methods of resistance welding may be described as follows:

Pressure welding is a process of welding metals in the highly plastic and/or fluid states by the aid of mechanical pressure. This process includes the resistance welding form of electric welding and the pressure type of thermit welding.

Spot welding is a resistance welding process wherein the weld is made in one or more spots by the localization of the electric current between contact points.

Resistance butt welding is a resistance welding process wherein a butt joint is employed.

Upset welding is a resistance butt welding process wherein the surfaces to be welded are brought together in firm contact before the electrical circuit is closed; and when said surfaces have been raised to the desired welding temperature, the electrical circuit is opened and the upset pressure applied. The operation of the machine may be manual, semi-automatic, or fully automatic.

Flash welding is a resistance butt welding process wherein the welding heat is developed by the passage of current in the form of an arc across a short gap between the surfaces to be welded, these surfaces being kept slightly separated until they have flashed off to parallelism and have reached the desired temperature. The electrical circuit is then opened and the upsetting movement takes place. The operation of the machine may be manual, semi-automatic, or fully automatic. The name "flash"

arises from the fact that during the heating period oxidizing metal is thrown off in a shower of sparks.

Flash-upset welding is a combination of the flash and upset butt welding processes. This process starts as a flash weld and ends as an upset weld, the electrical circuit remaining closed for a short interval during the upsetting movement. The operation of the machine may be manual, semi-automatic, or fully automatic.

Seam welding is a resistance welding process wherein the weld is made linearly between two contact rollers or a contact roller and a contact bar.

Percussive welding is a resistance welding process wherein electric energy is suddenly discharged across the contact area or areas to be welded, and a hammer blow is applied simultaneously with or immediately following the electrical discharge.

Electro-static percussive welding is a percussive welding process wherein a condenser is used to supply the energy.

Electro-magnetic percussive welding is a percussive welding process wherein the stored energy in a magnetic field is transformed by the collapse of the field to supply the energy.

Induction resistance welding is a resistance welding process wherein the heating current is caused to flow in the parts to be welded by electro-magnetic induction without any electrical contact between the source and the work.

Progressive induction seam welding is an induction resistance welding process wherein the heating current is caused to flow in the parts to be welded and to cross the seam of the weld in a localized zone while there is relative progressive traversing movement of the parts to be welded and the welding zone along the seam.

Resistoflex. Tubing made in sizes up to and including 1/2 inch inside diameter, from a flexible synthetic resin, insoluble in gasoline, oil, ether, and alcohol. Has extreme lightness (weight about one-half that of aluminum), great toughness and strength, good elasticity, and a high degree of flexibility. Used chiefly in fuel and brake lines; in lubrication systems for automotive equipment, Diesel engines, and aircraft; in chemical and process industries for conveying solvents and oils; in hydraulic lines; and in fuel and oil handling equipment.

Resistor. A resistor consists of an electrical conductor which, because of its physical dimensions and the type of material of which it is made, limits the current in an electric circuit by transforming a portion of the electrical energy into heat, which may be stored temporarily in the resistor, but is ultimately dissipated to the surrounding medium, which is usually the atmosphere. The

property of dissipating the absorbed energy by the transference of heat to the surrounding medium is known as the "radiating capacity," and the property of absorbing energy by storing it in the form of heat, as the "thermal capacity" of the resistor.

Resistors are the basis for a wide range of controlling devices for motors. For this purpose they are made in the following different types: The tube type which consists of a tube of fireproof insulating material such as porcelain on which the resistance wire is wound; the bar type, which consists of a flattened tube or an iron bar insulated with a fireproof material on which the resistance wire is wound; the ventilated wire type, which consists of an insulated support on which the resistance wire is wound; the edgewise type, which consists of a conductor of narrow ribbon wound edgewise on a suitable mandrel, after which it is dipped in a thin mixture of fireclay or other fireproof insulating material; the plate type, which consists of a molded plate of insulating material in which the resistor wire is imbedded, the contact points projecting through the surface of the plate; the cast-iron grid type, which consists of a special grade of cast iron of suitable shape, so as to insure sufficient length and mechanical strength.

Small resistors which are wire-wound on porcelain or composition forms are widely used in communication and other low-current circuits. A coating of cement or vitreous enamel is often applied over the windings for insulation and mechanical protection. Composition resistors, such as the silicon-carbide type, are used to obtain high resistance values, and metallized resistances consisting of a homogeneous resistance film on an insulating base such as glass or porcelain are used for high voltage and ultra high frequency applications. There are also many special types: resistances which are extremely accurate in value, resistances which vary little in value with temperature changes, resistances which are practically non-inductive, etc.

Resolution of Forces. This expression, which is used by mechanics, relates to the finding of two or more components of a given force. See Force.

Resonance. In alternating current circuits containing resistance, inductance and capacity, it may happen that at certain frequencies the positive reactance of the inductance becomes equal in value to, and is neutralized by, the negative reactance of the capacity. This is called a *resonance condition,* under which the current flow with a given electromotive force is limited solely by the resistance of the circuit. For small resistance values, the current may, therefore, reach very high values.

Resonance is an important factor in communication circuit design and the values of inductive and capacitive reactances are carefully chosen to produce or avoid resonance conditions at certain frequencies. A resonant condition in power circuits may result in considerable damage due to excessive current flow.

Resultant. See Force.

Retrofits. See Numerical Control.

Return Traps. Return traps are used for returning the water of condensation from a heating system back to the boiler, and for handling the water from both open and closed heaters. The principle of operation is that of allowing water under a low pressure to enter a chamber elevated above the boiler, and, when filled, of closing the connection with the low-pressure system and admitting steam at boiler pressure, thus causing the water to flow into the boiler by gravity. These operations are all automatic.

Reverse-Current Trip. A reverse-current trip is an arrangement for tripping a circuit-breaker when the current flowing through the circuit in a direction the reverse of that in which it flows under normal conditions, has reached a predetermined value. The tripping may be accomplished by either the attracting or the releasing of the armature of the magnetic circuit, depending upon the arrangement of the series and potential coils. It will be easily understood that the direction of current in the potential coil will always be the same, regardless of whether the current is flowing from a generator to a battery, or from a battery to a generator, and tending to motor it. On the other hand, the direction of the current in the series coil will be reversed under similar conditions.

Revolite. Flexible form of laminated cloth or paper treated with Bakelite resinoid differing from the usual laminated sheets in that the flexibility is much greater. Laminations 1/8 inch thick can be bent over a 1/4-inch bar without cracking or splitting. Among the applications are acid-proof linings; packing rings; transformer parts; vacuum-brake parts; gaskets; belting; upholstery for automobiles, trolley cars, buses, and airplanes; table covers, desk tops, etc.

Revolution Counter. See Speed Indicators.

Rex. Rex is the trade name for an aluminum oxide abrasive which is used for grinding either soft or hardened steel. Rex is a product of the electric furnace, the process of manufacture being similar to that of alundum.

Rhenium. A metallic element with a specific gravity of 21.4 and a melting point of 3170 degrees C. The metal is silvery-

white in appearance and is hard, ductile, and malleable. Indicated uses include electrical contacts and filaments.

Rheostat. A rheostat is an adjustable resistor so constructed that its resistance may be changed without opening the circuit in which it is connected. Resistors in electrical circuits can be made adjustable in a number of ways. One way is by short-circuiting sections of a resistance; another way is by shifting the terminals so as to include between them more or less resistance. A resistance device that is used for controlling electric current is called a rheostat; these instruments are usually adjustable. A rheostat switch is usually a part of the rheostat and consists of an insulating base on which are mounted, on the circumference of the circle, a number of stationary contacts and an arm pivoted at the center of the circle which carries a contact that makes connection with the stationary contacts. The stationary contacts are connected to various sections of the resistance of the rheostat, and the switch is used for cutting these sections of resistance in and out of circuit. In small rheostats the moving contact may slide along a bare section of the winding. A carbon rheostat is composed of disks or granules of carbon. By rotating the control knob a varying degree of pressure forces the carbon pieces closer together, thus increasing the number of points of contact and decreasing the resistance. A convenient form of rheostat, when large currents are to be controlled, is the water rheostat, which is usually a tank containing a solution of either salt or soda in which metal plates are suspended. The resistance of the rheostat is controlled by the depth to which the plates are submerged.

Rhodium. A metallic element with a specific gravity of 12.44 and a melting point of 1966 degrees C. This hard metal is malleable at temperatures above 800 degrees C. Uses include fountain pen nibs, heating elements for high-temperature electrical resistance furnaces and thermo-couple points.

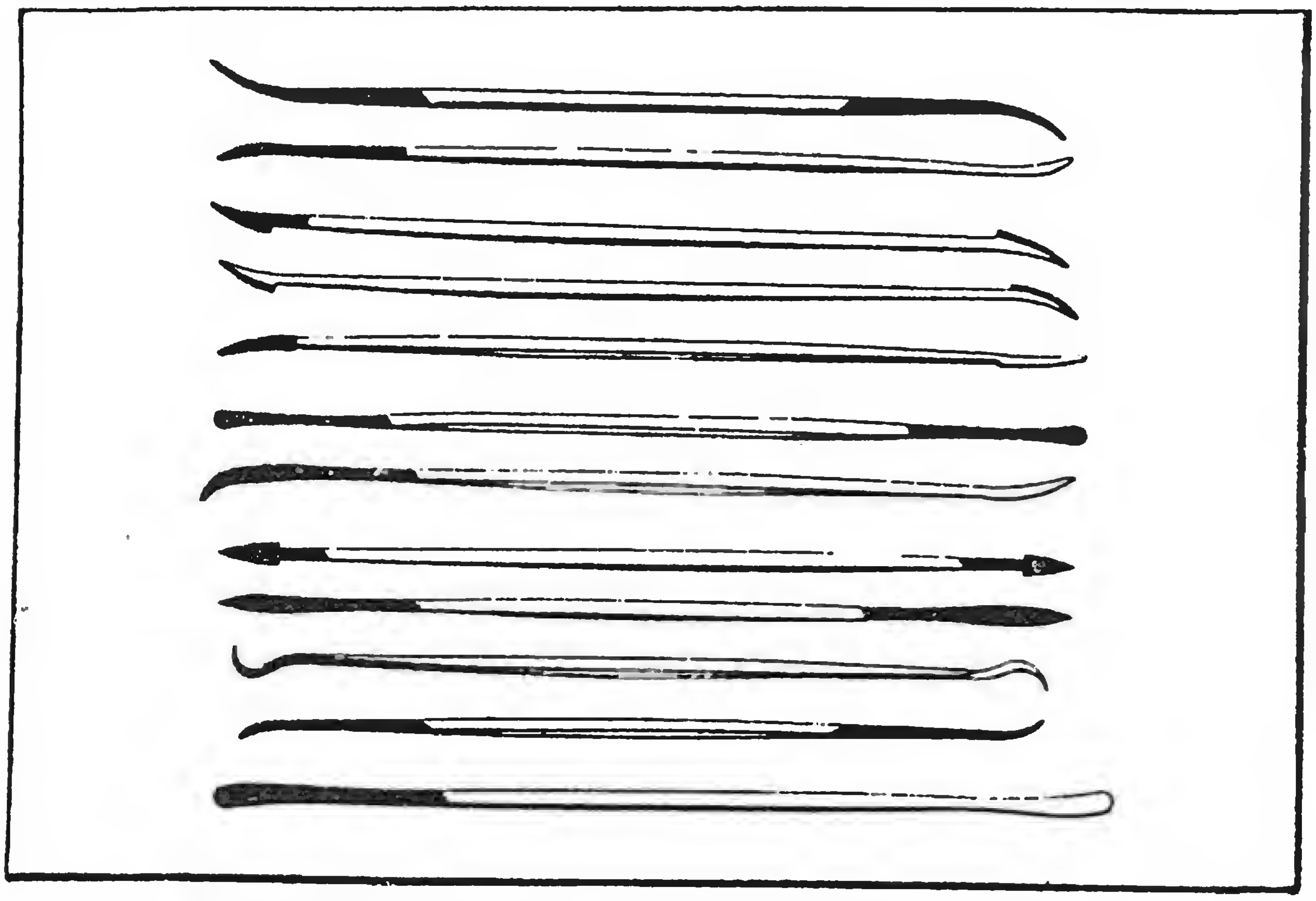
Rice Coal. Rice coal is of such size that the pieces will not pass a screen of 3/16-inch mesh, but pass a screen of ⅜-inch mesh. Rice coal is often used for power plant purposes.

Riedler Pump. The difficulty of operating pumps at high speed when they are equipped with ordinary self-closing valves in the pump cylinder is due to slip and fractional resistance, resulting from the flow of the water through the valves at high velocity. The Riedler pump (invented by Prof. Riedler) is designed especially for high-speed operation. One large valve is used instead of a number of small ones, thus decreasing the friction of the

water in the valve passages. The first pump equipped with Riedler valves was constructed in 1884. The suction and discharge valves are practically the same and are composed of three concentric bronze rings, which serve to open and close a like number of concentric openings in the valve-seat. The valves have a high lift and the area through them is such as to reduce the velocity of the water enough to prevent excessive frictional resistance. The closing of the valves is positively controlled by an eccentric which transmits motion through an oscillating wrist plate and connecting-rods. The valves open automatically and remain open during practically the entire stroke, and then the closing is effected quickly and positively by the valve-gear. These pumps are adapted to various classes of service as well as for large capacities and high pressures.

What is known as the Riedler *express pump* is designed for much higher speeds than the ordinary type, and differs from the latter in regard to the arrangement and operation of the valves. The suction valve is the principal feature. This valve is concentric with the plunger and is annular in form.

Rifflers. Rifflers are small bent files which may be obtained in a large variety of shapes, sizes, and cuts (see illustration). In use, the riffler is held lightly in the hand and is worked back and forth over the surface to be smoothed; thus, it is filing on a small scale. The most common form is the "spoon" riffler, which comes



Die-sinkers' Rifflers—Lengths from 6 to 7 Inches

in many different grades of curves, its name describing its shape perfectly. Next in point of usefulness is the flat riffler, which is made in different shapes and widths to take care of the flat surfaces and panels in the die impressions. Other styles are the "hook" riffler, the "knife" riffler, and the "round taper" riffler.

Ring Gage. This type of gage, as the name implies, is in the form of a ring and it is used for checking shafts, plugs, or other external diameters. The American gage design standard includes plain ring gages in sizes above 0.059 to and including 12.260 inches.

The ring type of gage is widely used for checking external screw threads. The hole in the gage is threaded and a limited amount of adjustment is provided. The American gage design standard has an adjusting screw and a locking screw which provides a positive lock without introducing stresses in the gage body which might tend to cause distortion.

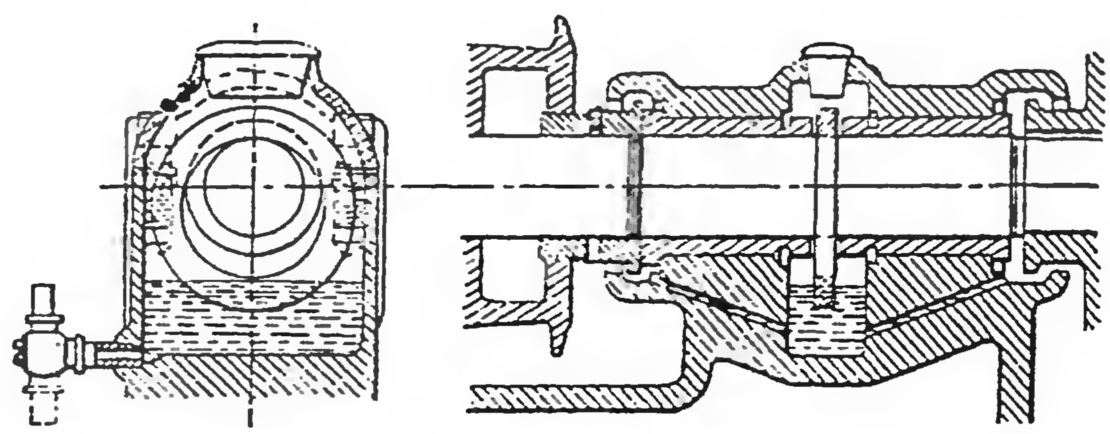


Fig. 1. Ring-oiled Bearing

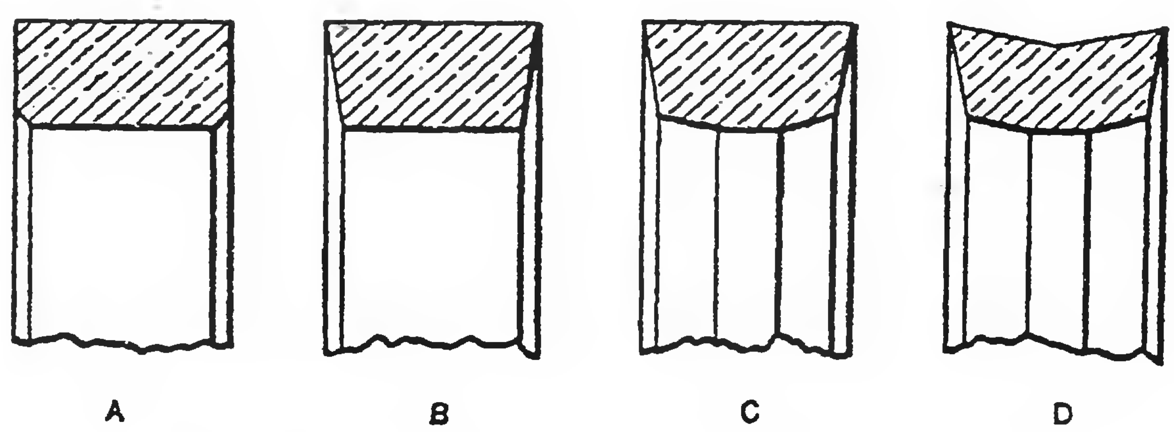


Fig. 2. Oil-rings of Different Cross-section

Ring Oiling. The ring method of oiling a bearing is so named because the oil is carried from a reservoir in the base of the bearing, up over the journal or shaft, by a loose-fitting ring

which receives a rotary motion as the shaft revolves. The lower section of this ring is immersed in the oil so that the entire ring is flooded whenever it is revolved. The two sectional views (Fig. 1) give an example of a long bearing (for a disk grinder), with a ring, and grooved bearing brasses. A well is cored out and has a draining pipe, which is turned downwards to empty the well. When in the vertical position indicated, the well is filled until the pipe is filled nearly to the top, and the inlet is then plugged. The square shoulders on the pulley collar and the disk throw the oil off into the annular recesses whence it drains down into the well. No ribs or other projections should be fitted on the rings, as such arrangements produce a resistance to their passage through the oil bath, and bring them to a standstill. At high speeds, the centrifugal force renders the flow of oil from the ring to the journal difficult, and scrapers are used for diverting the oil into the oil channels. These, however, should never touch the ring, as they will then stop its motion. Self-oiling bearings having rings fast on the shaft are not much used.

Oil-ring Design: As an oil-ring-lubricated journal must be started dry or nearly dry, an oil-ring should be so designed that it will start promptly when the shaft begins to rotate. After the ring has once started, it should continue to rotate as long as the shaft turns. On a poorly designed bearing, it is not uncommon to see a ring start, stop, and repeat this action in regular cycles. When the oil gets on the ring, the coefficient of friction drops rapidly, but it should still remain high enough to rotate the ring. Other causes of rings sticking are unbalance in the rings due to blow-holes, lumps of solder, unsymmetrical design, or egg-shaped rings. As a general rule, the oil-ring should be made at least twice the diameter of the shaft. The oil cellar should be so proportioned and the oil overflow so located that, with a maximum oil level, the ring will dip into the oil to a depth equal to about one-third the diameter of the shaft. A ring should be heavy enough to stand up under production cuts.

The cross-sectional shape of the ring is important. A plain rectangular cross-section, such as shown at *A* (see Fig. 2), is often used. Rings of this kind can be easily machined from tubing. A better shape than the rectangle for the cross-section of an oil-ring is the trapezoid shown at *B*. It is sometimes necessary to have a ring fit the slot rather closely, and this shaped ring is less likely to bind in the slot if the machine happens to be a little out of level axially. A further refinement may be made by chamfering the bore as at *C*. For small light rings, this is particularly good, as it increases the specific pressure between the shaft and ring, thus enabling the ring, even though light in weight, to cut through the oil and get a better bite on the shaft.

The contour of the cross-section shown at D, effectively prevents oil-throwing. The oil collects at the two outer edges, and when thrown off, strikes the sides of the oil-ring slot, which prevents it from leaving the pedestal.

A fairly hard brass is a desirable material for small and medium sized oil-rings. Cast iron has been used with success, but this is not generally favored. It is claimed that washers of sheet metal, several of them running in one ring slot, have given satisfactory results. Very soft compositions or dead soft brass should be avoided, for if the oil becomes gritty, the rings will be charged like a lap, and will wear grooves in the journal.

Ring-Wound Armature. In electric generators or motors, a ring-wound armature is an armature in which the conductors are laid side by side and connected by threading the wire through the center of a ring-shaped armature core. This type has been superseded by the "drum-wound armature."

Risers and Feeders. Risers are openings in molds, similar to pouring gates, in which the metal rises and floats the dirt out of the mold. They should be placed where the dirt is most likely to accumulate. On large castings where there is considerable shrinkage, the riser is made large in order to supply metal to compensate for the shrinkage, and is known as a *feeder, header,* or *shrink-head.* The riser or feeder must be large enough so that it will not set before the casting. Linings and rolls are sometimes made longer than necessary in order to feed the shrinkage and catch the dirt. The surplus metal is called a *sinking head* and is cut off in the machine shop. A riser is not required when the dirt and shrinkage are taken care of in this way.

Rivet Driving. In driving cone-head or button-head rivets, they should be "plugged" squarely into the hole, care being taken not to bend over the point of the rivet but to upset it, filling the hole its entire length. A riveting hammer should be powerful enough to form a perfect head without rocking the hammer to work down the edges. The hammer should be started lightly until the rivet has settled into the hole somewhat, to prevent bending to one side. In driving any kind of rivets held or backed up by a dolly-bar or hand-hammer, the riveter must learn to run the hammer slowly until enough head is formed to hold the rivet in the hole, as otherwise the holder-on will have difficulty in keeping the hammer or dolly-bar on the rivet. Getting the rivets into the holes hot and "getting the heads up" is a necessary preliminary to obtaining tight work. For holding the rivet in position, there must be sufficient weight behind it to form a solid anvil against which it may be headed.

Riveted Joint Calking. See Calking.

Riveted Joints Classified. When plates to be joined by riveting overlap each other and are held together by one or more rows of rivets, a "lap joint" is formed. In a "butt joint" the plates are in the same plane and are united by a cover plate or butt strap, which is riveted to each plate. A combination lap joint consists of a cover plate inside or outside the lap, and three rows of rivets, the central row passing through the two plates and the cover, and having twice as many rivets as the other two rows. The term "single riveting" means one row of rivets in a lap joint or one row on each side of a butt joint; "double riveting" means two rows of rivets in a lap joint or two rows on each side of the joint in butt riveting. Joints are also triple and quadruple riveted.

Riveter, Electric Type. The "electric riveting" process consists in first heating the rivet by electrical means and then subjecting it to sufficient pressure to form the head. The machine used resembles the well-known spot-welder, and in its simplest form is provided with two opposing copper electrodes, the upper of which is movable vertically. After the rivet is in position, the upper electrode is brought down into contact with it. The current induced in the secondary winding of a transformer then flows through the rivet, quickly heating it to the required temperature; then the current is cut off and a greatly increased pressure applied, thus upsetting the rivet and forming the head. The heating of the rivet occurs so rapidly that there is little loss by radiation or conduction. Another type of electric riveter utilizes an electrode for heating and a separate set for forming the head.

Riveter, Hydraulic Type. Many riveters, especially of the large sizes used for boiler work, are operated by hydraulic pressure. Some riveters of this general type have a frame which is composed of two sections. The side which carries the cylinder and movable die is known as the *frame,* whereas the opposite side which carries the stationary die is known as the *stake.* The arrangement of the hydraulic cylinder on riveters of different make varies considerably. In general, there is a piston or plunger of comparatively large area which provides the necessary riveting pressure, and a smaller auxiliary plunger for returning the die preparatory to driving another rivet. Many hydraulic riveters are so arranged that two or three pressures may be obtained and, in some cases, there is a larger range of pressures.

Hydraulic Toggle Riveter: This type of hydraulic riveter is provided with a toggle mechanism through which motion is transmitted from the piston to the riveting plunger. The construction is similar in principle to that employed on many pneumatic riveters, but, instead of using air pressure, the piston is operated by water pressure. The advantage claimed for a riveter

of this type as compared with a direct-acting hydraulic riveter is that a much smaller cylinder is required, because the necessary increase of pressure for riveting is obtained by means of the toggle mechanism; consequently, the riveter occupies less space, is lighter in weight, and requires considerably less power to drive it than one of the direct-acting type.

Riveter, Pneumatic Type. One design of pneumatic riveter is so arranged that the piston of the air cylinder imparts motion to the riveting plunger through a combination of levers and toggles which give a gradually increasing pressure until the desired pressure is reached; then, by means of a simple lever movement, approximately the maximum pressure is maintained throughout the remainder of the die travel. This movement of the die under maximum pressure is sufficient to allow for ordinary variations in the length of rivets, size of holes, or thickness of plates after the machine has once been adjusted for a certain riveting operation. The *hydropneumatic compression riveter* is operated both by air and hydraulic pressure, as the name indicates. The air pressure is utilized for moving the plunger down to the rivet and then the pressure is greatly increased by hydraulic means.

Riveter, Rotary Vibrating Type. The rotary vibrating type of riveter may be operated in close corners or other places where there is not sufficient room for the rotating rolls, such as are used on rivet-spinning machines. These machines are also used for general riveting operations. The spindle of a well-known design is vibrated by an eccentric mechanism which transmits motion to the spindle by means of a hickory helve. A rubber ball is interposed between the top of the spindle and the end of the helve to absorb vibration. In addition to the vibrating motion, the spindle is positively rotated by means of a worm and gear, and provision is made for varying the speed of the spindle in order to secure smooth work. It sometimes happens that, with a fixed number of blows per second at a certain rotating speed, the spindle will strike in the same relative position, thereby causing a series of indentations on the rivet heads; hence, provision is made for varying the spindle speed in order to secure smooth work.

Riveter, Turret Type. This type of riveter is adapted for cold riveting. The principal feature of this riveter is a rotating turret-head on which four horns or noses are mounted. Any one of these noses may be indexed to bring a stationary rivet die into alignment with the movable die mounted on the plunger or ram.

Riveting Machines. The tools and machines designed for upsetting and forming rivet heads include several distinct types.

These special tools or machines for riveting may be divided into several general types. First, they may be classified according to the method of forming the rivet head, which may be either by (1) compression; (2) by a succession of rapid blows; (3) by rapid blows accompanied by rotary motion of the rivet set; (4) by combined compressive and rolling or spinning action; (5) or by the application of pressure to an electrically-heated rivet. "Riveting machines," according to common usage, differ from "riveters" in that the riveting operation with a machine is effected by a succession of blows or by a compressive rotating action, whereas a riveter merely subjects the rivet to compression. These compression riveters may be classified according to the power used for operating the riveting plunger. Thus there are hydraulic, pneumatic, hydropneumatic, and other types.

Rivets. Rivets are used as permanent means for fastening or joining together parts of metal structures. There is a head on each end of the rivet, one head being formed after assembling the parts, either by the application of pressure or a succession of

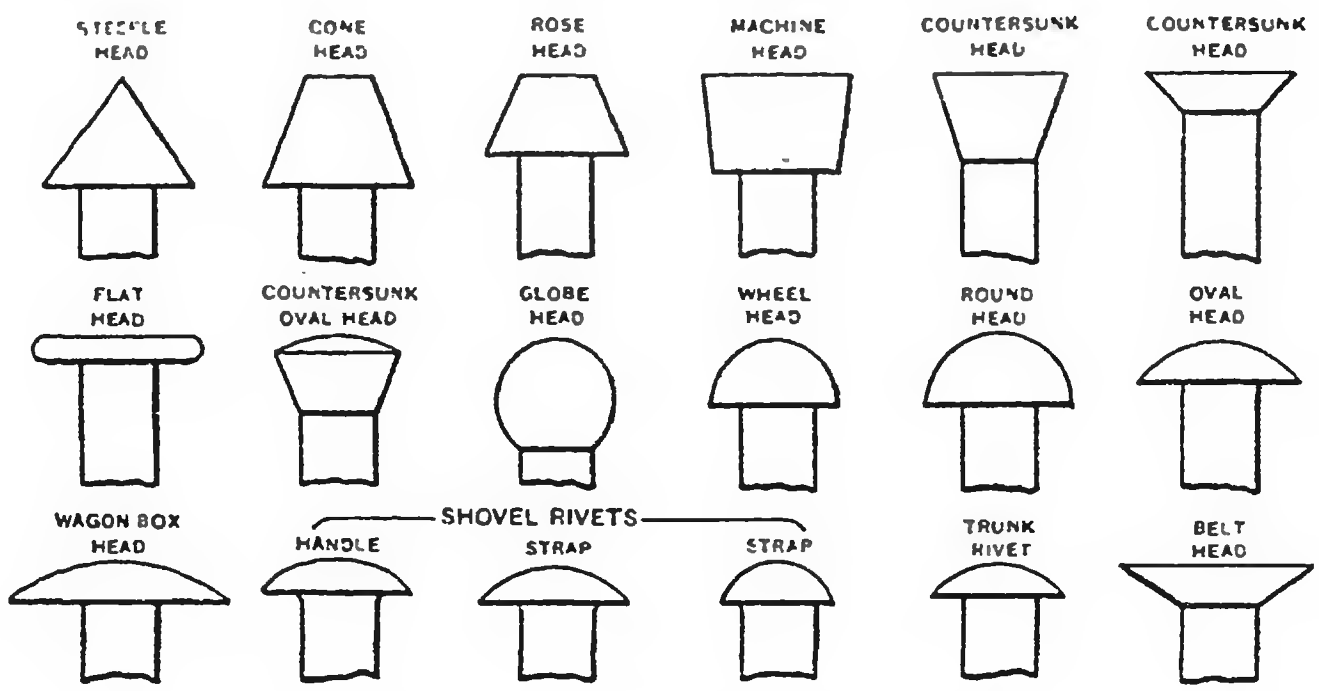


Fig. 1. Names of Rivet Heads

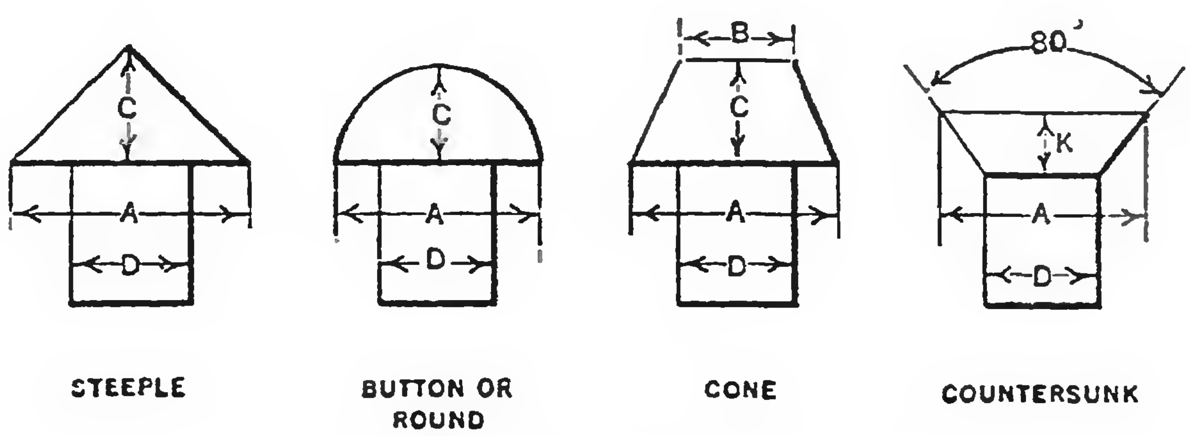


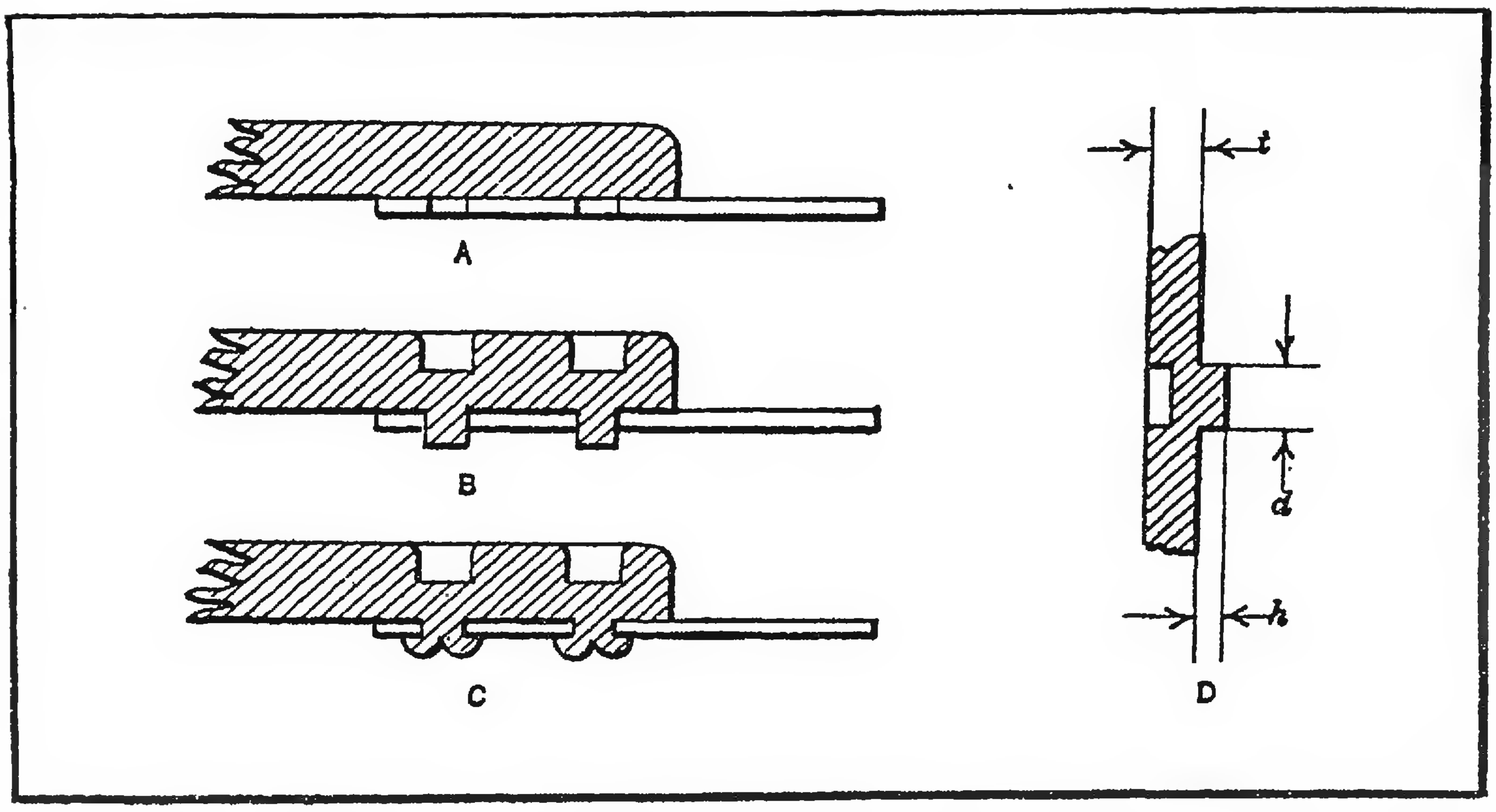
Fig. 2. Rivet Head Dimensions

blows. The form of the head varies, but is generally spherical or conical, the apex of the cone usually being cut off so that the head has the shape of a frustrum. Sometimes the head is countersunk in the plates held together by the rivet. Fig. 1 shows a number of different types of rivet heads. In order to form the head and fill the clearance space in the rivet hole, the rivet should have a length in excess of the thickness of the plate equal to about three-fourths the diameter for the countersunk head, and from 1.3 to 1.7 times the diameter for ordinary riveting. It is advisable to make the rivets of the same material as the plates in which they are used, to prevent corrosion from galvanic action; that is, iron rivets should be used for iron plates, steel rivets for steel plates, and copper rivets for copper plates.

Proportions which have been used extensively for the common types of rivet heads, are as follows: *Steeple head:* Diameter A (see Fig. 2) of the head equals twice the rivet diameter D, and height C of the head is equal to diameter D. *Button or round head:* Diameter A of the head equals 1.75 times rivet diameter D, and height C of the head equals 0.75 times diameter D. *Cone head:* The large diameter A of the head equals 1.75 times rivet diameter D, the small diameter B equals 0.9375 times diameter D, and the height C equals 0.875 times the diameter D. *Countersunk head:* The diameter A of the head equals 1.844 times rivet diameter D, and the height K equals 0.5 times diameter D. These proportions are based upon an included angle of 80 degrees. According to the American Standard, the included angle is 78 degrees and $A = 1.81\ D$; $K = 0.5\ D$. An included angle of 60 degrees is the common standard for bridge and structural work.

Rivets, Cold Formed. In permanently assembling various light parts, it is often possible to greatly reduce the cost and yet secure sufficient strength by cold forming in an assembling die, the rivet or rivets as an integral part of one of the assembled sections. Diagrams A, B and C illustrate how a steel spring is cold riveted to the heavier section. Plain round punches descend and form the rivets by forcing metal down through the holes in the spring (see diagram B); the metal at the edge is then turned back by the die as at C, thus completing the riveting at one stroke of the press. In this particular case, about sixty assemblies per minute are obtained.

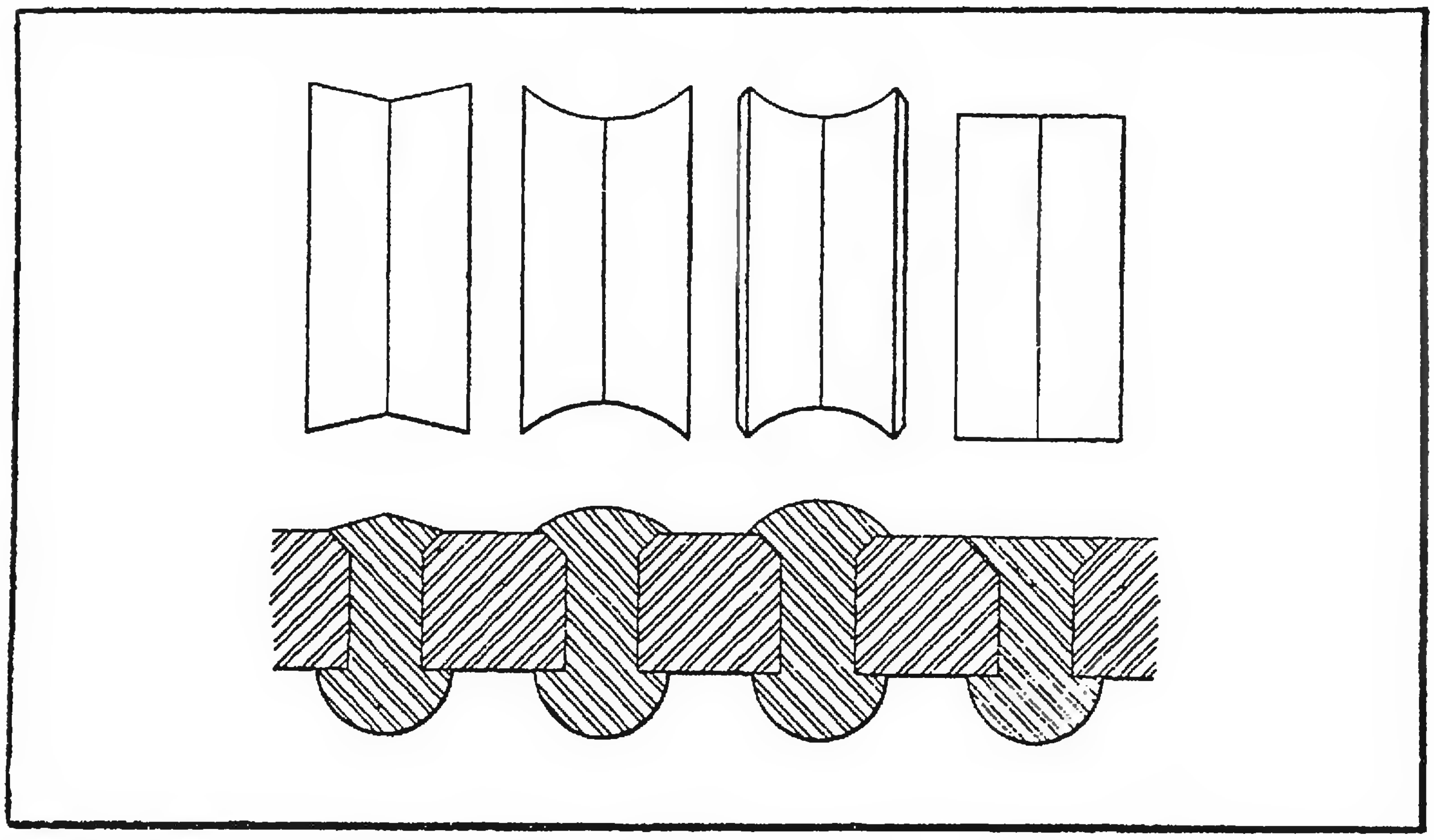
Embossed Dowels and Hubs: When dowel-pins are required to insure the accurate location of parts relative to each other, small projections or bosses may be formed directly on many die-made products, the projection being an integral part of the work and serving as a dowel-pin. Diagram D illustrates how the dowel is formed. The method may be described as a partial punching operation, as a punch penetrates about one-half the stock thick-



Rivets and Dowels Die-formed on Assembled Part

ness and forces the boss into a pocket in the die which controls the diameter and compresses the metal, thus forming a stronger projection than would be obtained otherwise. The height *h* of the dowel or boss should not exceed one-half of the dowel diameter *d* and *h* should not exceed one-half of the stock thickness *t*. This is a practical rule which may be applied either to steel or non-ferrous metals, such as brass.

Rivet-Spinning Machines. The rotary rivet-spinning machine forms the rivet heads by means of twin rolls which are carried at the end of a rapidly revolving spindle and are pressed against the rivet head. Four different forms of riveting rolls and



Rolls Used on Rivet-spinning Machines

the shape of the rivet heads which they produce are shown by the diagrams. A pair of these rolls is mounted upon a pin in the roll holder, and as they are pressed against a rivet head each roll revolves independently, thus rolling or spinning a rivet head to a form corresponding to the shape of the rolls. The spindle revolves quite rapidly, the speed for a machine having a maximum capacity of 3/8 inch being about 1000 R.P.M. In the case of a machine having a maximum capacity of 3/16 inch, the speed would be increased to about 2000 R.P.M. The spindle is pressed downward by means of a foot-treadle. Special designs of multiple-spindle rivet-spinning machines are sometimes used for duplicate work having a number of rivets which may all be riveted at the same time. One feature of rivet-spinning machines is the absence of noise which is characteristic of hammer-riveting.

Rivets, Pitch of. See Pitch of Rivets; also Back Pitch of Riveted Joint.

Rivet Steel. According to A.S.T.M. standard specifications, both structural and boiler rivet steel is made either by the open-hearth or electric furnace processes, or by both of these processes

Structural Rivet Steel: The tensile strength, according to standard specifications, is from 52,000 to 62,000 pounds per square inch; the minimum yield point is one-half the tensile strength, but not less than 28,000 pounds per square inch; and the minimum percentage of elongation in 8 inches equals 1,500,000 divided by the tensile strength. The phosphorus content must not exceed 0.06 per cent (acid) or 0.04 per cent (basic). The sulphur content is limited to 0.05 per cent; and if copper steel is specified, there should be not less than 0.20 per cent copper. The test specimen must withstand cold bending to 180 degrees flat on itself without cracking on the outside of the bent portion. This test specimen must be the full diameter of the bar as rolled.

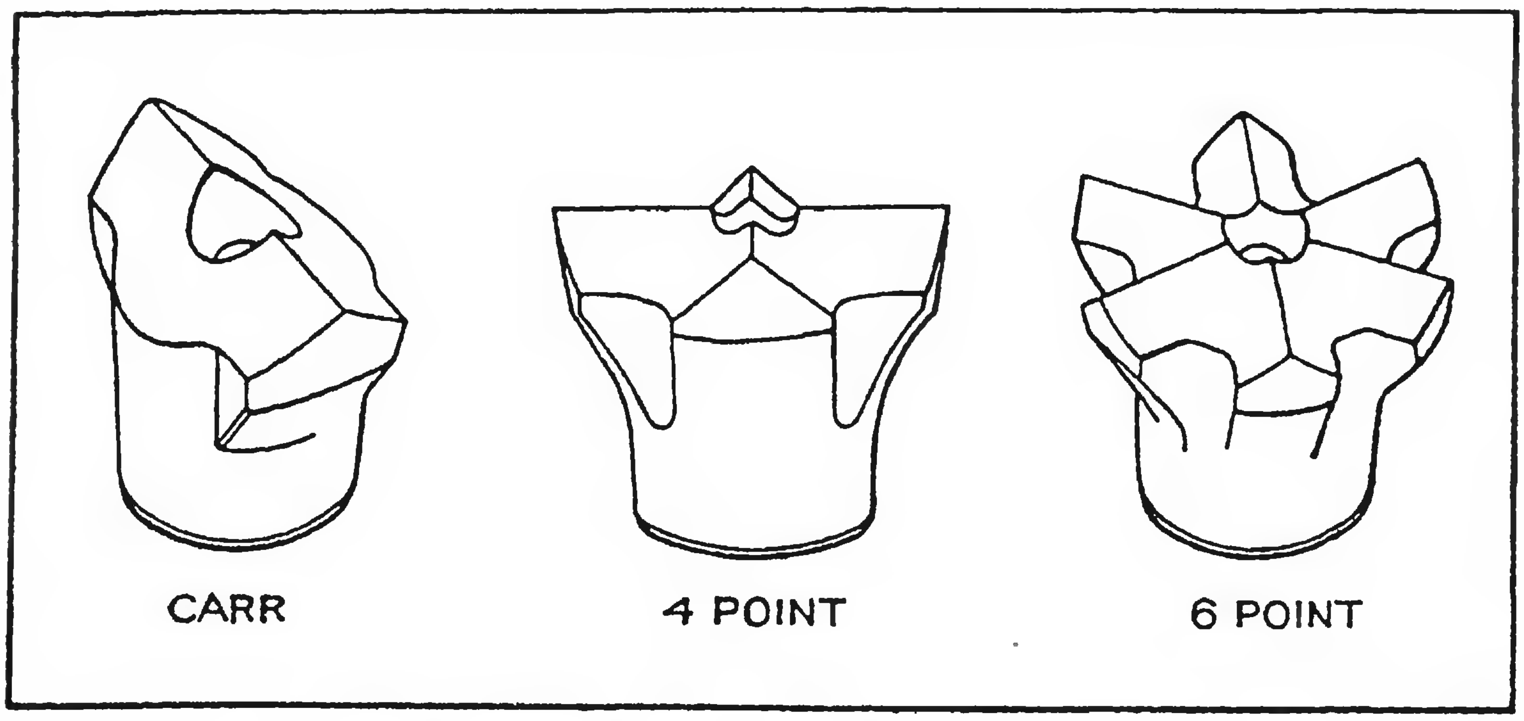
Boiler Rivet Steel: The standard strength requirements are as follows: Tensile strength, 45,000 to 55,000 pounds per square inch; minimum yield point, one-half the tensile strength; minimum percentage of elongation, 1,500,000 divided by the tensile strength, but it need not exceed 30 per cent. The manganese content is 0.30 to 0.50; the maximum phosphorus content, 0.04; and the maximum sulphur, 0.05 per cent. The *cold-bend test* requires bending the test specimen to 180 degrees flat on itself without cracking on the outside of the bent portion. The *quench-bend test* requires heating the test specimen to a light cherry red as seen in the dark (not less than 1200 degrees F.) and quenching in water, the temperature of which is between 80 and

90 degrees F. The quench specimen then is bent to 180 degrees flat on itself and must withstand this without cracking on the outside of the bent portion.

Rock Drill Bits. Detachable rock drill bits are made in three general types, as shown in the accompanying illustration. These are known as the Carr, or two-point, the four-point, and the six-point types. All types are made in sizes ranging from 1¼ to 3¼ inches in diameter, by increments of ⅛ inch. The four-point bit is the most popular. Probably 90 per cent of the detachable rock drill bits used today are of this type.

The service rendered by a bit before it is necessary to re-sharpen it depends upon the accuracy with which it has been ground, the angle of the cutting edge, and the character of rock being drilled. On four-point bits the included angle of the face is generally 120 degrees, and on six-point bits, 60 degrees; but this angle may be increased or decreased in accordance with the degree of hardness of the rock.

Rockwell Hardness Test. The Rockwell hardness tester is essentially a machine that measures hardness by determining the depth of penetration of a penetrator into the specimen under certain fixed conditions of test. The penetrator may be either a steel ball or a diamond sphero-conical penetrator. The hardness number is related to the depth of indentation and the number is higher the harder the material. A minor load of 10 kg. is first applied which causes an initial penetration; the dial is set at zero on the black-figure scale, and the major load is applied. This major load is customarily 60 kg. or 100 kg. when a steel ball is used as a penetrator, but other loads may be used when found necessary. The ball penetrator is 1/16 inch in diameter normally;



Three Types of Detachable Rock Drill Bits

but other penetrators of larger diameter, such as ⅛ inch, may be employed for soft metals. When a diamond sphero-conical penetrator is employed the load usually is 150 kg. Experience decides the best combination of load and penetrator for use. After the major load is applied and removed, according to standard procedure, the reading is taken while the minor load is still applied. The letters *B* and *C* were adopted for the two standard Rockwell scales, the letter *B* applying to tests with a ball penetrator of 1/16 inch diameter and a 100-kilogram major load, for testing relatively soft metals, and the letter *C* to tests with the diamond penetrator having a rounded point and a 150-kilogram major load. There are several other Rockwell scales.

Rod. A "rod" as the term is applied in rolling mill practice, is generally understood to be a round bar. The United States Government limits wire rods to sizes larger than No. 6 B. W. G. (0.203 inch) in diameter; all smaller sizes are termed *wires*.

In length measure, one rod = 5.5 yards = 16.5 feet = 25 links.

Rodding. In core making, rodding is the process of putting bars or rods in cores in order to strengthen them, so that they may be handled with less risk of being broken. Either loose rods placed in the core or rods held in a cast frame or skeleton may be used.

Rod Gages. See Gages for Rods.

Roebling Wire Gage. See Steel Wire Gage.

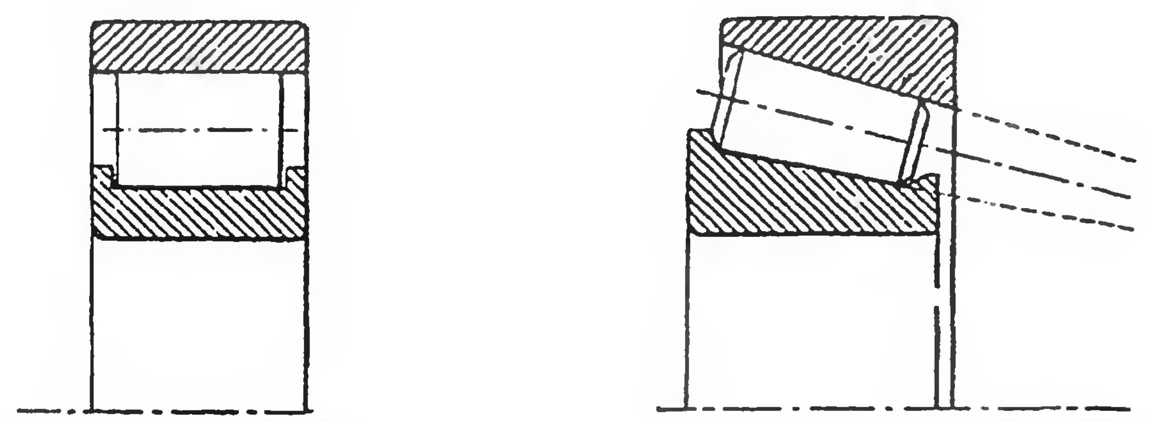
Rolled Gears. See Gears, Rolled.

Rolled Joint. This form of pipe joint consists of flanges on the pipes, which flanges are clamped between larger flanges by means of bolts. See Van Stone or Rolled Joint.

Rolled Splines. See Gears, Rolled.

Rolled Screw Threads. See Thread Rolling.

Roller Bearing. The load on roller bearings is supported by cylindrical or conical rollers interposed between two races, one race being mounted on the shaft and one other in the bearing proper. There are three principal designs of roller bearings. One is for straight radial loads, the lines of contact of the rollers with the races being parallel with the shaft axis, as shown by the left-hand diagram; another design is for combined radial and thrust loads (see right-hand diagram). With this design, the rollers are tapering so that the lines of contact of the rollers with the races, and the axis of the rollers, will intersect, if extended, at the same point on the shaft axis. A third design is intended for thrust or axial loads exclusively. Bearings for



Bearing for Radial Load

Bearing for Radial and Thrust Loads

radial loads may have solid rollers, or the hollow helically-wound type such as is used in the Hyatt bearing. Although anti-friction bearings have replaced a great many plain or sliding bearings, the trend is toward a much wider application, and evidently will include eventually the heaviest classes of service since modern anti-friction bearings not only greatly reduce friction losses, but lower maintenance and repair costs.

Roller Bearing Capacities. It is impracticable to give a general formula for determining the load capacities of roller or other anti-friction bearings. Different makes of bearings have basic load ratings which represent average or typical conditions, but these basic ratings vary according to the type and make of bearing and the operating conditions under which they have been established. Bearing capacities are influenced by such conditions as mountings, adjustment, lubrication, and protection against dust or other foreign matter. Because of the variations mentioned, bearing capacities should be based upon the manufacturer's recommendation so that the working loads will be in accordance with records of actual performance, which, in many instances, extend over long periods. According to one prominent manufacturer, a basic capacity rating of 100 per cent, suitable for general or typical machinery applications, might have to be reduced 20 or 30 per cent when bearings are subjected to severe shocks, as with the crankshafts of internal combustion engines or when used continuously for exceptionally high speeds.

In determining the capacity of roller bearings, one prominent manufacturer considers the speed; the shaft hardness, when no inner race is used; whether the shaft rotates and the outer race remains stationary, or vice versa; and finally, the nature of the service. The basic capacity of bearings decreases as the speed increases. The hardness of the running surfaces also affects capacity, so that shaft hardness is a factor when there is no in-

ner race. If the application is such that the shaft remains stationary and the outer race revolves, the load relationship is not the same as with the revolving shaft, especially for bearings operating directly on the shaft where different shaft hardnesses are used. The nature of the service takes into account such factors as whether it is continuous or intermittent, whether the load is steady or fluctuating, whether the bearing is subjected to shock, overloads and vibrations. The protection from grit or other foreign matter and the attention in regard to lubrication are other service factors.

Roller Blind Guard. This is an arrangement that is used to a limited extent for protecting the slides of machine tools from chips and grit. It consists of a wide roller mounted at the end of the bed of the machine, having a spring action so that it automatically winds up (similarly to a window shade), a strip of water-and-oil proof material which is attached to the roller at one end and to the moving slide at the other end. As the slide travels, the blind is drawn out or wound up, thus keeping the ways covered at all times. The arrangement has been applied to planers and surface grinding machines.

Roller Chain. A roller chain differs from a block chain in that bushings and rollers are inserted between the links instead of solid blocks. The rollers are mounted on bushings, and rivets (which pass through the bushings) hold the side links in place. Roller chains of the detachable type are so constructed that the links may be taken apart readily. Roller chains are much stronger than block chains and are used very extensively. They are adapted to higher speeds than block chains and are generally employed when the amount of power to be transmitted is comparatively high.

Roller Chain Nomenclature. The following nomenclature for roller chains conforms to the practice recommended by the Society of Automotive Engineers: A *roller link* is an inside link consisting of two inside plates, two bushings and two rollers; a *pin link* is an outside link consisting of two pin-link plates assembled with two pins; an *inside plate* is one of the plates forming the tension members of a roller link; a *pin-link plate* is one of the plates forming the tension members of a pin link; a *pin* is a stud articulating within a bushing of an inside link and secured at its ends by the pin-link plates; a *bushing* is a cylindrical bearing in which the pin turns; a *roller* is a ring or thimble which turns over a bushing; *assembled pins* are two pins assembled with one pin-link plate; a *connecting link* is a pin-link with one side plate detachable; a *connecting-link plate* is the detachable pin-link plate belonging to a connecting link; an *offset link* is a link con-

sisting of two offset side plates assembled with a bushing and roller at one end and an offset-link pin at the other; an *offset-link pin* is a pin used in offset links.

Roller Chain Speeds. The maximum speeds for roller chain transmissions have commonly been related to the speed of the chain but scientific observations made by a prominent chain manufacturing company have demonstrated that the destructive action between chains and sprockets is not due to high chain speed (feet per minute) so much as to high sprocket speed (revolutions per minute). Thus the difference in the behavior of two drives is not necessarily due to the difference in chain velocity. The destructive action due to impact between roller and sprocket is proportional to the weight of a chain link and to the square of the velocity with which the roller strikes the sprocket, and inversely proportional to the weight of a chain link and to the square of the impact between roller and sprocket is proportional to the product of the pitch times the number of revolutions per minute.

If P = pitch; S = maximum number of sprocket revolutions per minute; A = projected area of roller; W = weight per foot of chain, then

$$S = \frac{C}{P}\sqrt{\frac{A}{WP}}$$

where C is a constant to be determined by tests. Experience shows that when C is equal to 2000 this formula gives the maximum sprocket speeds for satisfactory results, and that, in general, it is desirable to use sprocket speeds not greater than 80 per cent of the maximum speed S.

When one keeps within the proper range with respect to the number of revolutions per minute, there is no known limit to the permissible chain velocities except where centrifugal force becomes great enough to stress the chain beyond its proper working load. By using a sufficiently large number of teeth on the sprockets, roller chains have been driven at velocities as high as 4000 feet per minute, transmitting five times their ordinary rated horsepower at that speed. Such drives, of course, require special attention.

High-speed roller chains are essentially double-roller chains. The weight, pin bearing area, and width of these chains is double that of a single-roller chain of the same pitch, and they are capable of transmitting twice the power at the same speed. The sprocket teeth are cut with the same cutters as are used for single chains of the same pitch and roller diameter. The very satisfactory performance of these double chains, coupled with their low cost, has greatly extended the field of usefulness of the roller chain, and except where extreme quietness of action is required,

they will fill all ordinary requirements for either low or high speeds.

Roller Chain Sprocket Design. See Sprocket.

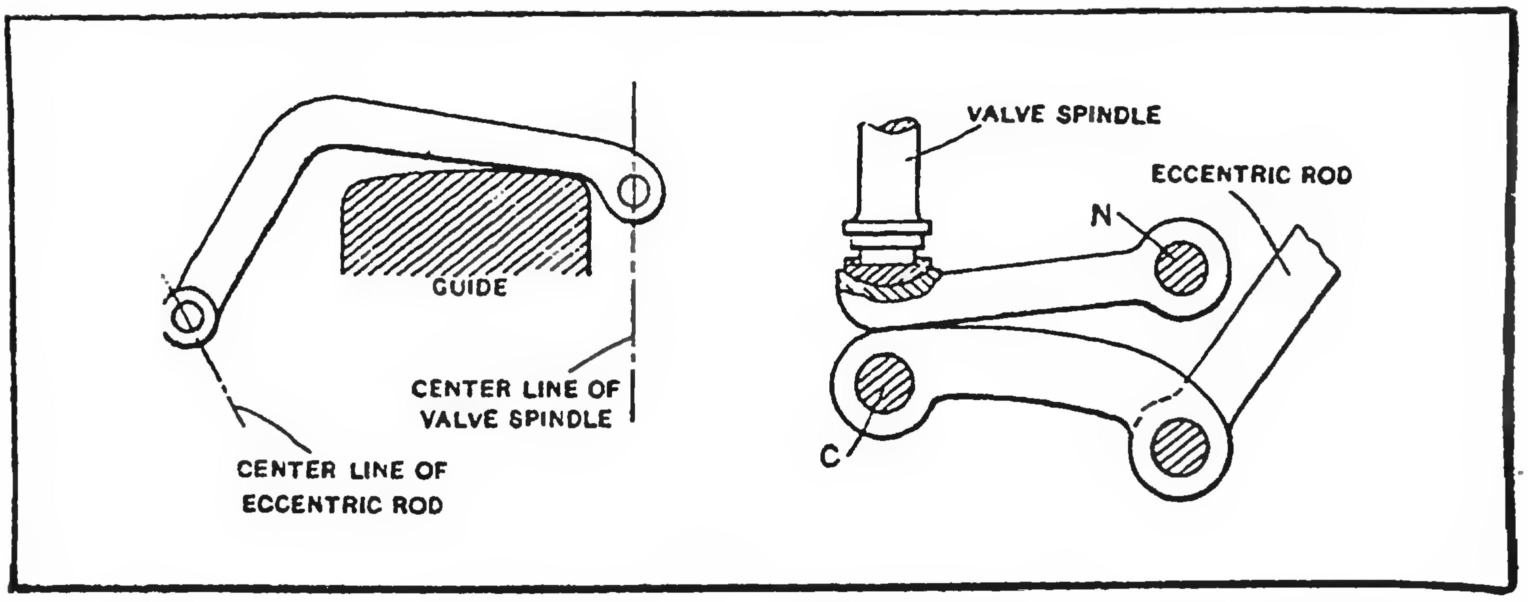
Roller Follower. This is the part of a cam-operated device which is directly actuated by the cam. A roller at one end of the follower or driven member presses against the cam surface in order to reduce the frictional resistance.

Roll Extrusion. Roll extrusion is a method of forming large-diameter thin-wall parts having integral internal flanges, ribs or stiffeners. It consists essentially of expanding a hollow cylindrical blank both radially and axially against the bore of a rotating die ring by means of a power driven roll. Ribs can be formed in the bore of the blank by a suitably shaped roll on a mandrel, and the part extruded by rolling down the material between the ribs.

Roll Feed Mechanism. When a power press is used for producing plain blanks or shallow drawn or formed parts from strip stock, a roll feed mechanism is commonly used. The stock passes between two rolls mounted one above the other, which feed it under the dies a predetermined amount for each stroke of the press. These rolls are geared together and rotated by a ratchet-and-pawl mechanism. The ratchet wheel is mounted at the end of one roll and is operated by a rod connecting with a crank attached to the end of the crankshaft. By varying the position of the crankpin, the feeding movement of the stock can be changed as may be required. These feeding rolls may be located so as to feed the stock laterally or between the sides of the press frame; that is, the feeding mechanism may be located at either side of the press table or at the front or rear. The feed-rolls of presses are commonly provided with an automatic release. This release is so arranged that the grip of the rolls upon the stock is momentarily released at every stroke as the punch descends, and is a desirable feature when pilots are used in the ends of the punches, in order that the stock will be free to move slightly in case the pilots are not in exact alignment with the pierced locating holes. See also Power Press Roll Feeds.

Rolling Friction. Rolling friction is the force that retards the motion of a body rolling over a surface. See Friction.

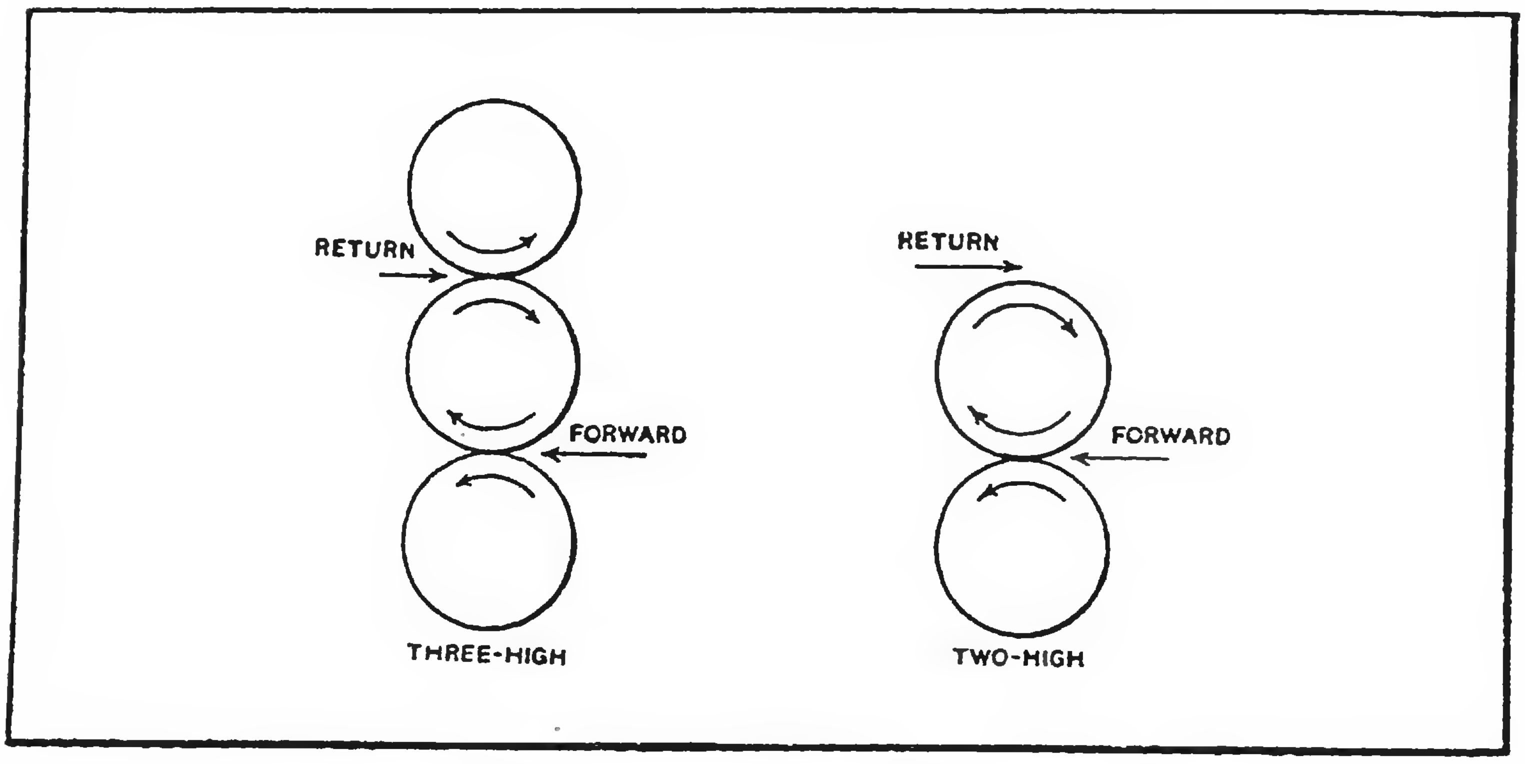
Rolling Levers. So-called "rolling levers" may be classified as a special form of cams. Rolling levers are employed to actuate the valves of large gas engines as well as the poppet-type valves of steam engines. These levers may be divided into two classes —the single-lever type (see illustration) and the double-lever



Rolling Lever of the Single-lever Type **Rolling Lever of the Double-lever Type**

type. In the first case the lever rolls on a fixed guide, and thus has a continuously moving fulcrum, which travels from one end of the guide to the other. In the second case the levers are fulcrumed at fixed points, as at *C* and *N*, and roll upon each other. The levers should have a pure rolling motion in order to insure a minimum of wear. The valves should be opened quickly and should close with a constantly decreasing velocity, so as to seat quietly and without shock.

Rolling Mills. The term "rolling mill" is applied to machines used for rolling bars, rails, sheets, etc., and also to the plant in which the rolling mill operations are conducted. Considering the machines, rolling mills are used for producing steel or wrought-iron bars of uniform cross-section and flat sheets or plates, by passing a short heavy piece of stock between rolls which gradually reduce it to the required form. The rolls are either cast-iron or steel cylinders which, for rolling bars, rails, etc., have



Action of Three- and Two-high Rolling Mills

a series of grooves for gradually reducing a heated ingot, billet, or bloom to the cross-sectional shape required. For rolling flat sheets or plates, plain cylindrical rolls are employed. After the stock is caught between the rolls, it is drawn through by friction, and the reduction in thickness resulting from each pass causes a corresponding increase in length. The change in cross-sectional shape of a bar or the reduction in thickness of a flat plate due to one passage through the rolls is comparatively small, so that several passes are required.

Rolling mills of the "two-high" and "three-high" types are shown diagrammatically by the accompanying illustration. In the *two-high* mill, the metal is acted upon on its forward pass, but not on its return; in the *three-high* type, the metal is acted upon on both passes. To avoid the idle pass, two-high rolls are often made reversing. In that case, as soon as the bar is passed through the rolls, the direction of the rolls is reversed and the bar is passed through in the opposite direction. In the two-high non-reversing mill, all impurities are worked toward one end of the bar, because the metal passes through in the same direction each time, but in the three-high and the reversing two-high mills, the impurities are worked toward the middle of the bar, as the bar is rolled from each end.

Blooming mills are used to reduce ingots to blooms, billets, or slabs. *Billet mills* are used to reduce the blooms to a section $1\frac{1}{2}$ inch square or larger so that these billets may be used for bars and rods. *Sheet-bar mills* reduce slabs and blooms to sheet bars so that they may be used in sheet and tin mills. *Beam mills* are used for heavy beams and channels 12 inches and over. *Universal mills* have vertical and horizontal rolls, so that all four sides are rolled simultaneously, and are adapted for rolling square-edged plates and various wide-flanged shapes.

Rolling Screw Threads. See Thread Rolling.

Ronay Process. This is a method for briquetting metal chips without the use of a binding material. The material to be briquetted is subjected to a heavy hydraulic pressure, approximating 35,000 pounds per square inch. Cast iron, steel, brass, bronze, aluminum, and copper chips, borings, and filings, as well as graphite, ore, flue dust, etc., may be briquetted in this way.

Rontgen Rays. See X-ray.

Root. In mathematics, a root of a given quantity, is the quantity which, when repeated as a factor a number of times equal to the index of the root, will give as a product a given number. For example, $\sqrt[4]{81} = 3$, because 3 repeated as a factor 4 times gives 81 as the product.

Root Diameter of Screw Thread. The root diameter is the diameter of a screw across the bottom or root of the thread, measured at right angles to the axis of the screw. The *root* is the bottom of the groove which forms a thread, whether the thread be external or internal. According to the American Standard definitions for screw threads, the terms "root diameter" and "core diameter" have been replaced by the term "minor diameter," which also replaces "inside diameter" as applied to the thread of a nut. The minor diameter is the smallest diameter of an external or internal screw thread.

Root-Mean-Square (RMS.). The square root of the mean of the squares of the instantaneous values for one complete cycle of an alternating current is the root-mean-square or effective value and it is usually abbreviated rms. Unless otherwise specified, the numerical value of an alternating current refers to its rms. value. The rms. value of a sinusoidal wave is equal to its maximum, or crest value, divided by $\sqrt{2}$. The word "virtual" is sometimes used in place of rms., particularly in Great Britain.

Rope. See Arc Light Rope; Cable-laid Rope; Haulage Rope; Hemp Rope; Hoisting Rope; Manila Rope Strength; Wire Rope.

Rope-Lay Cable. In electricity, this is a single-conductor cable composed of a central core which is surrounded by one or more layers of spirally- or helically-laid groups of wires. A rope-lay cable differs from a concentric-lay cable in that in the former the main strands are stranded.

Rope, Non-Spinning. Non-spinning rope is a special type of wire rope made from eighteen strands of seven wires each. The object of so-called "non-spinning" hoisting rope is to prevent a free load suspended at the end of a single line of rope from rotating. The spinning of a rope endangers the life of workmen, and the constant attention required to guide the load is difficult and expensive. Non-spinning hoisting rope is constructed by first placing six strands of seven wires each (Lang's lay) around a hemp core. These six strands are then covered with an outer layer composed of twelve strands with seven wires to the strand laid in "regular" lay—that is, the wires in the strands are twisted to the left, but the strands themselves are twisted to the right or wound around the wire rope in the direction of a right-hand screw thread. Ropes of this type are made from various materials, according to the strength required for the service for which they are intended.

Rope Splicing. When two pieces of rope are joined by unlaying the strands and weaving or intertwining the strands of one end with those of the other, the operation is known as *splicing.*

Short Splice: The first step in making a short splice is to unlay or untwist the strands at the end of each rope. After the ropes are placed together, as shown at *A* (see Fig. 1) the strands on one side, as shown at *d*, *e*, and *f*, are either held together by the left hand or are fastened together with twine, in case the rope is too large to be held by the hand. The splicing operation is started by taking one of the strands as at *a*, and passing it across or over the adjacent strand *d* and then under the next strand *e*, after having made an opening beneath strand *e*. The strands *b* and *c* are next treated in the same manner, first one and then the other being passed over its adjoining strand and then under the next successive one. These same operations are then repeated for the strands *d*, *e* and *f* of the other rope. The splice will now appear as shown at *B*. In order to make it stronger and more secure, the projecting strands of each rope are again passed diagonally over the adjoining strands and under the next successive ones. The splice should then be subjected to a strong pull, in order to tighten the strands and make them more compact. The projecting ends of the strands should then be cut off, thus completing the splice as shown at *C*. For making the openings beneath the strands on the rope, what is known as a *marlin spike* is generally used. This is merely a tapering, pointed pin made of wood or iron.

Long Splice: When a rope has to pass through pulley blocks, or in case any increase in the size of the rope would be objectionable, the short splice is not suitable and the long splice should be employed. The diameter of a long splice is the same as that of the rope and, if the work is done carefully, the place where the ends are joined can scarcely be distinguished from the rest of the rope. The ends of each rope are first unlaid or untwisted the same as when making a short splice, but for a distance about three times as long. These ends are then placed together so that each strand lies between two strands of the other rope, the same as for a short splice. One of the strands is next unlaid and then a strand from the other rope is curled around into the groove thus made, as indicated at *A* (see Fig. 2), strand *a* having been unlaid and strand *b* from the other rope end, put into its place. Care should be taken to twist strand *b* so that it will lie in its natural position into the groove previously occupied by strand *a*, as the neatness of the splice will depend partly upon the care with which this part of the work is done. This operation is then repeated in connection with strands *c* and *d*, strand *c* being unlaid and strand *d* twisted around to occupy the groove thus made. The splice will now be as shown at *B*, and the next step is that of disposing of the protruding ends of the strands. After these strands have been cut to about the length shown at *B*, two of

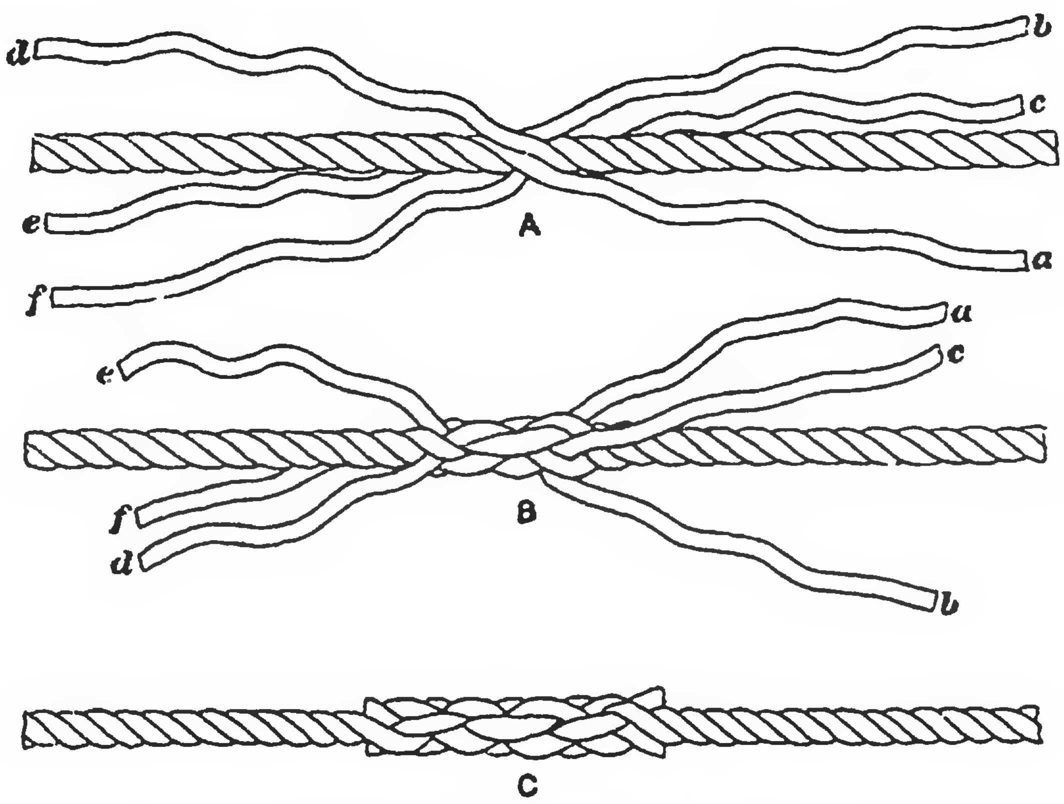


Fig. 1. Method of Making a Short Splice

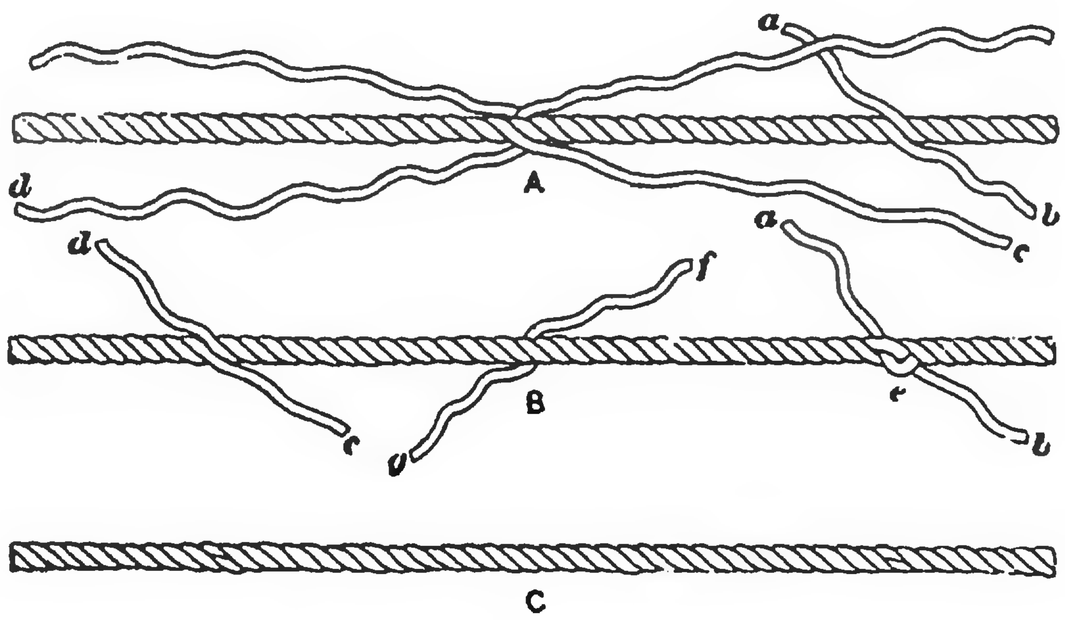


Fig. 2. How a Long Splice is Made

the strands, as at *a* and *b*, are first reduced in size by removing about one-third of the fiber; these ends are then tied by an overhand knot as shown at *e*. After tightening this knot, the protruding ends may be disposed of the same as when making a short splice, or by passing them over the adjoining strand and through the rope, under the next one. By gradually removing the fiber each time the end is passed across an adjoining strand, the enlargement of the rope at this point may be made very slight and scarcely noticeable. The strands *f* and *g* which remain in their original positions in the center of the splice, and also the strands *c* and *d* are disposed of in a similar manner, thus completing the splice as shown at *C*. See Eye-splice.

Rope, Steel-Clad Hoisting. This is a wire rope which has each strand covered with flat steel strips wound spirally around them in order to provide additional wearing surface. These ropes are used in cases where the rope is subjected to extreme wear, and give additional wearing surface without sacrificing the flexibility. The life of the wire rope exposed to great wear may be increased from 50 to 100 per cent by this construction.

Rope Transmissions. Transmission of power by means of ropes operating over grooved sheaves or pulleys has been replaced largely by motor drives or motors in conjunction with short-center belt drives. The rope method, which has been used chiefly in textile mills, was designed especially for comparatively long center-to-center distances. There are two systems of rope transmission which are known as the American or continuous system and the English or multiple system. In the *American or continuous system* of rope driving, one long rope is wound around the driving and driven pulleys several times or until all of the pulley grooves have been filled; the rope is then conducted from the last groove of the driven to the opposite groove of the driving pulley by means of an idler, which is held at the required angle. The *English or multiple system* differs from the American system in that a number of parallel ropes, one in each groove in the pulleys, are used instead of a single rope that is wound around the pulleys continuously. The required tension is obtained by the weights of the ropes, no tension carriage being employed; hence, in the multiple system, the driving and driven sheaves should be located far enough apart to obtain the required tension.

Ropes: Cotton ropes are generally considered better than Manila ropes for power transmission because they will transmit more power and will wear longer. The initial cost, however, is greater. The life of driving ropes depend upon their size and the conditions under which they work. The most economical diameters for cotton ropes range from 1½ to 1¾ inches, the larger size being commonly used for transmitting considerable power. Regarding the relative merits of the three- and four-strand ropes, the former is superior in that it will transmit the same power with a fewer number of ropes. The four-strand rope, however, has the advantage of stretching less, and there is a larger surface in contact with the pulley grooves; it is also capable of a stronger splice. A well-made four-strand rope is, moreover, nearly as strong as a three-strand rope, but it requires more skill to splice it. A three-strand rope rotates once for every nine feet of travel; a four-strand rope rotates once for every twelve feet of travel; and a six-strand rope rotates once for every twenty-four feet of travel.

Rope Speeds: The speed of driving ropes usually varies from 2000 to 5000 feet per minute. The most economical speed is between 4500 and 5000 feet per minute. If the speed is too low, the ropes are likely to slip, and if it is too high, the action due to centrifugal force affects the efficiency. As the ropes operate in V-shaped grooves, the loss due to centrifugal force is less than with belt drives; hence, ropes are adapted to higher velocities.

Wire Rope Transmission: The application of wire rope for the purpose of transmitting power was first made in 1850, in Switzerland. With this system of transmission, an endless wire rope is employed which runs over large sheaves, the grooves of which are usually filled with rubber or wood. Ordinarily, the sheaves are of cast iron and are made as light as possible. In addition to the rubber and wood fillers, various other materials have been used for filling the grooves, such as tarred oakum, jute yarn, and leather. With rubber and leather fillings, considerably more power can be transmitted than when using wood-filled sheaves. As a general rule, this system of transmission should not be used for shorter center-to-center distances than 50 feet, and it may be employed without supporting idler sheaves, for distances up to 300 feet. For greater distances, guide sheaves should be used at points 300 feet apart or less. Double-groove sheaves are also used in some cases; these are spaced 300 feet apart and serve to divide the transmission system or rope into a number of independent sections.

Rose Chucking Reamer. This is an end-cutting reamer used for enlarging cored or drilled holes. The cylindrical part of the reamer has no cutting edges, but merely grooves cut for the full length of the reamer body, providing a way for the chips to escape and a channel for lubricant to reach the cutting edges. There is no relief on the cylindrical surface of the body part, but it is slightly back-tapered so that the diameter at the point with the beveled cutting edges is slightly larger than the diameter further back. The back-taper should not exceed 0.001 inch per inch. This form of reamer usually produces holes slightly larger than its size and is, therefore, always made from 0.005 to 0.010 inch smaller than its nominal size, so that it may be followed by a fluted reamer for finishing.

Rosin. Rosin, which may vary in color from a light amber to almost black, is the residue left after the volatile turpentine has been distilled from the sap of certain pine trees. This hard residue is used in making varnishes, paints, and soaps.

Rotary Blower. A rotary blower, also known as a "positive blower," is a blower consisting of a casing in which two moving

elements revolve in opposite directions, one or both of which are called *impellers*. The impellers are of double-lobe cycloidal form, so that they engage with each other and force air between them, as they rotate, from the inlet to the outlet. Rotary blowers are positive in their action and are used for furnishing blast for cupolas, gas and oil burners, furnaces, ash conveyors, pneumatic tube service, etc.

Rotary Carburizing. See Carburizing by Rotary Method.

Rotary Converter. This is an electrical machine used for converting alternating current into direct current. See Synchronous Converter.

Rotary Engine. The rotary type of steam engine differs from the reciprocating type in that the steam pressure is applied to some form of piston, or series of pistons, which is connected directly to the main shaft and revolves about the axis of the cylinder. Many attempts have been made to design a rotary engine that could compete with reciprocating engines. The chief theoretical advantage of the rotary principle is that the power is utilized directly to produce rotary motion without any intervening mechanism, thus eliminating a reciprocating piston and cross-head, and an oscillating connecting-rod, with their mass, inertia and vibration. The object of inventors has been to design a rotary engine that would not only possess the advantage of directness in the application of power, but, in addition, compactness and simplicity of construction. The principal disadvantages of most designs have been leakage, internal resistance or friction, and failure to use the steam expansively, all of which result in excessive steam consumption. The importance of the rotary type has become much less since the development of the steam turbine. The chief distinction between the rotary engine and the turbine is that the former is operated by pressure action, whereas, in the turbine, the kinetic energy of a mass of steam moving at high velocity imparts motion to the rotor or rotating member.

Rotary Files and Burs. Rotary files and burs are used with power-operated tools, such as flexible- or stationary-shaft machines, drilling machines, lathes, and portable electric or pneumatic tools, for abrading or smoothing metals and other materials. Corners can be broken and chamfered, burs and fins removed, holes and slots enlarged or elongated, and scale removed in die-sinking, metal patternmaking, mold finishing, toolmaking and casting operations.

The difference between rotary files and rotary burs, as defined by most companies, is that the former have teeth cut by hand with hammer and chisel, whereas the latter have teeth or flutes

ground from the solid blank after hardening, or milled from the solid blank before hardening. (At least one company, however prefers to differentiate the two by use and size: The larger-sized general purpose tools with ¼-inch shanks, whether hand cut or ground, are referred to as rotary files; the smaller-shanked—⅛-inch—and correspondingly smaller-headed tools used by diesinkers and jewelers are referred to as burs.) Rotary files are made from high-speed steel and rotary burs from high-speed steel or cemented carbide in various cuts such as double extra coarse, extra coarse or rough, coarse or standard, medium, fine, and smooth. Standard shanks are ¼ inch in diameter.

There is very little difference in the efficiency of rotary files or burs when used in electric tools and when used in air tools, provided the speeds have been reasonably well selected. Flexible-shaft and other machines used as a source of power for these tools have a limited number of speeds which govern the revolutions per minute at which the tools can be operated.

The carbide bur may be used on hard or soft materials with equally good results. The principal difference in construction of the carbide bur is that its teeth or flutes are provided with negative rather than a radial rake. Carbide burs are relatively brittle and must be treated more carefully than ordinary burs. They should be kept cutting freely, in order to prevent too much pressure, which might result in crumbling of the cutting edges.

At the same speeds, both high-speed steel and carbide burs remove approximately the same amount of metal. However, when carbide burs are used at their most efficient speeds, the rate of stock removal may be as much as four times that of ordinary burs. It has been demonstrated that a carbide bur will last up to 100 times as long as a high-speed steel bur of corresponding size and shape.

Rotary Milling Machine. Castings or forgings which are so shaped as to be readily clamped or released from a fixture are sometimes milled by a continuous circular milling operation. The continuous rotary milling machine is intended for milling large quantities of duplicate parts. The castings or forgings to be milled are held in a fixture near the edge of the table and, as the latter revolves, one piece after another passes beneath the revolving cutter (or cutters) and is milled or faced. As the finished parts come around to the front of the machine, they are removed by the operator and replaced by rough pieces without stopping the machine, so that the milling operation is practically continuous. A fixture for continuous circular milling must be designed so that the work can be removed quickly and without stopping the rotation of the table. The increased production that has been effected in many cases by substituting continuous rotary milling

for some other method is due to reducing the non-productive time of the machine by avoiding the necessity of stopping to set up work and then restarting the machine; by avoiding the need of returning the table to the starting point after each traverse; and by overcoming the necessity of having the machine idle while the operator is setting up work, or the operator idle while the machine is running.

Rotary Planers. The rotary planer or "end milling machine," as it is sometimes called, is especially adapted to the planing or slab milling of heavy castings or forgings. The distinguishing feature of a rotary planer is the large circular cutter head which carries inserted tools or cutters which successively cut away the metal as the cutter head revolves. The slide which carries the cutter head and driving mechanism of some rotary planers, is mounted on a horizontal bed and automatically feeds along this bed, when the machine is in operation. The part to be planed or milled is attached to a stationary work-table. Other rotary planers have a cutter head which remains stationary and a work-table which is given an automatic feeding movement. This type may have either a fixed cutter head or one that can be adjusted vertically. There are also several other variations in the design of rotary planers. Some machines are mounted upon a circular sub-base so that the bed carrying the cutter-slide can be swiveled, for planing the ends of long heavy parts at an angle. For finishing both ends or sides of the work at the same time, *duplex rotary planers* are used. This form consists of two planers mounted on one bed. One cutter head may be attached to a fixed base and the other to a swiveling base, or both heads may have fixed bases. The size or rated capacity of a rotary planer is equivalent to the diameter of the circle described by the tools in the cutter head.

Rotary Pumps. Rotary pumps are designed to operate with a continuous rotary motion instead of a reciprocating movement. In these pumps, the liquid is trapped between the revolving blades or wings of an impeller and the outer pump casing, and is forced around from the suction side to the discharge side. Pumps of this class may have either two or more lobes on each impeller. Rotary pumps, when properly designed, are simple and reliable, but usually the percentage of slip is comparatively high and leakage is liable to become excessive as the result of wear, especially when pumping against considerable pressure. Pumps of this type are used principally for thick or heavy liquids, or for liquids containing pulp, malt, or similar materials. They have also been applied to many machine tools for supplying oil to the cutting tools.

Rotary Shears. Rotary or circular shears are so named because the shear blades are in the form of disks. These disks are mounted on parallel shafts which rotate in unison. Shears of this kind are used for cutting curved sheets or for circular work. For the latter, the sheet or plate is held at the center of the disk to be cut, by a clamp which allows the sheet to revolve when the shears are cutting.

Rotor. When an important member of a machine revolves within a stationary casing or outer member, the rotating part is often called a rotor. For example, in a centrifugal pump, the rotor is a rotating element provided with vanes, which draws in air or liquid at the center and expels it at a high velocity at the periphery. The rotor of a steam turbine revolves within its casing as the steam impinges alternately against the rotor blades and the stationary casing blades. The rotating member of a generator or a motor is often referred to as a rotor. Various other rotating parts are known as rotors.

Roto Shaving. This term is applied to a special method of machining surfaces by means of cutters having helical teeth of fine pitch. Both the cutter and the work rotate, and this method is applicable in sizing and truing cylindrical surfaces and also the flat or end surfaces of shoulders or flanges. The stock removed by this process usually ranges from 0.010 to 0.015 inch on the flat or end surfaces, and about 0.020 inch on the diameter of cylindrical parts. The cutters are about 7 inches in diameter and usually are beveled. In some cases, a double-beveled form is used for machining, simultaneously, a cylindrical surface and an adjacent flat surface on a shoulder or flange. If a cylindrical surface is longer than the cutter width, the cutter may be traversed axially; and on long cylindrical parts of uniform diameter, the cutter axis usually inclines relative to the work axis in order to concentrate the maximum cutting action in a restricted area at the point of intersection. The roto shaving process is applied to certain jobs in place of grinding where the hardness does not exceed 38 Rockwell. Roto shaving is done in machines designed especially for this purpose.

Rottenstone. A weathered siliceous-limestone that is used as an abrasive for wood and metal finishing.

Round Chisel. This chisel is intended for the cutting of oil grooves or other grooves having a round bottom. The point of the chisel is round and the end surface is ground off at an angle to produce a cutting edge.

Round File. Round files (also called "rat-tail") are made both in the taper and blunt forms, and the cut is mostly bastard.

Round files are used either for enlarging round holes or shaping internal surfaces for which quadrangular sections would be unsuitable. The blunt shape is ordinarily used for the heavier classes of work. Both square and round files are made in "slim" forms, which are of regular length but of smaller cross-section.

Routing. Routing is a name given the operation of milling when the feeding movements of the work are controlled by hand, in order to follow an irregular outline, as when roughing out the impressions in drop-forging dies, etc.

Royalties on Patents. The customary royalty paid by manufacturers for the privilege of manufacturing and marketing patented mechanical devices may be either a certain percentage of the selling price or a certain fixed amount for each article manufactured, but the amount varies in almost every case because of the endless variety of conditions that affect royalties. It is not feasible to give general figures, as a royalty which is too high in one case may be entirely too low in another. For instance, when the manufacturer must invest in new equipment, and when the cost of selling a product is likely to be high, it is apparent that the manufacturer should have a larger royalty than would be required if the risk assumed were less. Because of these variable factors, 5 per cent royalty might be fair to both patentee and manufacturer under given conditions, and too low under other conditions. In other words, it is not feasible to establish the royalty by considering what someone else has done, but rather to establish it on a business basis, considering the facts covering the particular case under consideration.

Royalty Contracts. Royalty contracts are usually made on the basis of the inventor receiving a certain per cent of the retail selling price, or in some cases a percentage of the price obtained by the manufacturer. A much better arrangement is an agreed amount per article. In some cases the inventor agrees to take a certain proportion of the profits. This is usually a very poor arrangement, as the inventor is in effect and usually in fact a partner, and may become liable for the debts of the business; and in any case he has to find out what the profits are, which is often a matter for much argument and contention. The manufacturer should agree to keep an accurate account of the number of articles sold and to report and remit at stated times. He should also agree to allow the inventor free access to his books during business hours, and should agree to swear to the correctness of the books and the reports if required to do so by the inventor. Sometimes it is possible to give the articles consecutive serial numbers, which makes the accounting easier, and sometimes the inventor furnishes name-plates or labels at so much apiece, which

the licensee affixes to the article. The main considerations are to see that the contract is definite as to what is to be done, and the exact time that it is to be done, and to provide that if it is not done, all rights shall revert to the inventor.

Rubber. Rubber is obtained from certain trees and bushes found in the tropical regions of America, Africa, and Asia. Commercial rubber contains a number of foreign substances which can be removed by mechanical washing and drying. The washed and dried rubber is then treated according to the purpose for which it is to be used. In engineering, one of the most common uses of rubber is for electrical insulation. When rubber is to be used for this purpose, the washed and dried product is passed between rollers and pressed into sheets, after which it is cut up into pieces, again passed through the rollers, and compounded with various mineral substances, hydrocarbons, and sulphur, this process being known as "compounding." From 60 to 70 per cent of mineral substances may be added to the rubber gum before the essential qualities of the rubber cease to predominate. Commercial insulating rubber, for example, generally contains only about 30 per cent of rubber, while it may contain from 30 to 65 per cent of zinc oxide, up to 30 per cent of whiting, from 1 to 12 per cent of litharge, from 2 to 4 per cent of paraffin, and from 2 to 4 per cent of sulphur. A number of other substances are also present in small quantities. "Hard rubber" is defined as a rubber compound hard enough to be machined and polished. Hard rubber is vulcanized—that is, the soft rubber has been treated with sulphur so as to change it into a harder product than the original rubber.

Synthetic Rubber: Synthetic rubber production in the United States is based chiefly on the use of petroleum and alcohol. Natural rubber is made up of hydrogen and carbon atoms. Hydrocarbons for making synthetic rubber may be obtained from petroleum and from carbohydrates such as molasses, potatoes, grains, and other fermentable materials. The carbohydrates are first fermented to obtain alcohol which is converted into a hydrocarbon. The alcohol is obtained from raw materials such as natural gas, potatoes, grains, sugar, and molasses. The most important of the synthetic rubbers is the "Buna S" type. Buna S rubber is made from butadiene (about 75 per cent) and from Styrene (about 25 per cent). Butadiene can be obtained from oil refineries, natural gas, alcohol, or acetylene. The alcohol for making the butadiene may be made by fermenting grains, potatoes, etc., or it may be made from refinery gas. Butadiene is a hydrocarbon substance very similar to the chief constituent of natural rubber but it is not rubber. The butadiene molecules, once obtained, must be linked together in a chain or structure called a "polymer" (meaning "many molecules" as against a

"monomer" or "single molecule"). This linking together of the butadiene molecules would take place if the butadiene was allowed to set for several weeks untouched; but as this would be too slow for production purposes, another chemical is added to speed the process. This new chemical is called a "catalytic agent" and the process of polymerization is known as catalysis. To improve the quality of the synthetic rubber, other chemicals are added and polymerized with butadiene. This is called "copolymerization." After polymerization, a synthetic latex is obtained from which synthetic rubber can be obtained by coagulation with an acid, the same as with natural rubber. In other words, a "rubber polymer" is made synthetically, which has much the same characteristics and uses as natural rubber, and it can be vulcanized, compounded, and mixed with other materials. There are various other kinds of synthetic rubber such as Butyl, Neoprene, Buna N, Thiokol, etc.

Rubber Belts. Rubber belts generally are made up of 28-, 32-, and 36-ounce duck, and their ultimate tensile strength varies from 900 to 1500 pounds per square inch according to the fabric used. The higher frictional resistance of rubber belting, as compared with leather, is offset by the heavier weight (0.0478 pound per cubic inch, as against 0.038 pound per cubic inch for leather belts) which results in centrifugal force having a greater effect. Owing to the nature of a rubber belt (which is made up of plies) it is desirable to avoid extremely small pulleys whenever possible.

Rubber belts are made either with a special friction surface or with a rubber cover and in almost any width. The number of plies ranges from two to fourteen. The various brands vary slightly in tensile strength and weight. The average weight of rubber belting per square foot and ply is: 0.3699 pound for 28-ounce duck; 0.3893 pound for 32-ounce duck; and 0.4923 pound for 36-ounce duck. To find the weight per lineal foot of a rubber belt, multiply the weight per square foot and ply by the number of plies and the width of the belt, in inches, and divide by 12.

Rubber Belt Velocities. Owing to the greater effect of centrifugal force, the velocity of a rubber belt varies according to the cotton fabric used. The following are the most effective speeds for different cotton fabrics: 3000 feet per minute for belts made of 28-ounce duck; 2700 feet per minute for belts made of 32-ounce duck; and 2400 feet per minute for belts made of 36-ounce duck. These velocities cannot be exceeded without decreasing the effective pull. The limiting velocities at which the effective pull of a rubber belt equals the working stress minus the centrifugal force are as follows: 3800 feet per minute for belts made of 28-ounce duck; 3500 feet per minute for belts made of 32-ounce duck; and 3200 feet per minute for belts made of 36-ounce duck.

Rubber Bond Grinding Wheel. Rubber wheels are bonded with special mixtures of rubber, and then vulcanized. Wheels of this class have substantially the same advantages as elastic wheels, except that they can be made harder and thinner to meet more severe conditions. Both elastic and vulcanized wheels are used for cutting off tubing, wire, thin sheets of steel or brass, and parts that are difficult to hold while cutting off with the commonly used tools. See also Bonding Processes for Grinding Wheels.

Rubber-die Forming. See Guerin Process of Metal Forming, and Marforming.

Rubbing Machine. Convex, flat, and concave surfaces of wood and metal can be sanded, rubbed, or otherwise finished and polished by means of a portable rubbing machine. This machine is made in both floor and ceiling types.

Rugan's Experiments. These were a series of experiments undertaken in England by Prof. H. F. Rugan for the purpose of determining the conditions connected with the growth of cast iron and its causes. See Cast-iron Growth.

Ruhmkorff Coil. See Induction Coil.

Run. The following are definitions of the term "run" as given by the National Tube Co.: (1) A length of pipe that is made of more than one piece of pipe. (2) The portion of any fitting having its ends "in line" or nearly so, in contradistinction to the branch or side opening, as of a tee. The two main openings of an elbow also indicate its run, and when there is a third opening on an elbow, the fitting is a side outlet or back outlet elbow, except that when all three openings are in one plane and the back outlet is in line with one of the run openings, the fitting is a heel outlet elbow or a single-sweep tee or sometimes a branch tee.

Running Balance. When a part such as a drum, rotor, crankshaft, pulley, etc., is properly tested for balance while revolving, and any appreciable lack of balance is corrected on the basis of such test, the part is said to be in running or dynamic balance. Special balancing machines are used to determine the magnitude and location of unbalanced masses while the part is revolving; hence, the test is applied under operating conditions, which is not true of the test for static or standing balance.

Running Flange. This is a central guide-link used on silent chains for keeping the chain on the wheel. This guide-link is inserted in every alternate link or pitch of the chain and a groove is turned on the wheel into which this link will fit. The running

flange may also be provided at the outside edges of the chain, overlapping the edges of the wheel.

Running Rope. This term is applied to wire rope consisting of 6 strands with 12 wires each. It has a hemp core in the center of every strand with the 12 wires arranged around the core, and then a central hemp core about which the 6 strands are arranged. The construction produces a rope more flexible than the regular 6 by 19 hoisting rope, but for the same diameter the running rope has only two-thirds the strength of the hoisting rope. It is used for hawsers and mooring lines.

Rust. See Oxidation.

Rust Joint. This is a kind of joint employed to secure a permanent connection that is either steam-, gas-, or water-tight connection. The joint is made by using a stiff paste which oxidizes the iron, the whole rusting together and hardening into a solid mass. It cannot generally be separated except by destroying some of the pieces. One recipe is 80 pounds of cast-iron borings or filings; 1 pound of sal-ammoniac; and 2 pounds of flowers of sulphur, mixed to a paste with water. See also Cements for Joints.

Rust Prevention. When the atmosphere, sea water, acids, or similar substances with which iron or steel comes into contact, attack the iron by forming oxides or rust upon its surface, corrosion is said to take place. Iron and steel cannot stand exposure to the atmosphere, particularly when excessive moisture is contained in the air, for any length of time, without the protection of some covering or coating which excludes the moisture and which, in itself, is not attacked by the influence of the atmosphere. The various preventives which follow have been recommended by different men in the mechanical field.

Resin and Oil: Melt 4 ounces of resin in 1 quart of linseed oil and mix with 2 gallons of kerosene oil. The mixture is readily applied with a cloth or brush, and can be easily removed.

Caoutchouc, Turpentine and Oil: To preserve steel from rust, dissolve 1 part caoutchouc and 16 parts turpentine with a gentle heat, then add 8 parts boiled oil, and mix by bringing them to the heat of boiling water. Apply to the steel with a brush, the same as varnish. It can be removed again with a cloth soaked in turpentine.

Varnish and Turpentine: To make a mixture that will prevent hardware and machinists' tools from rusting, take one-half pint of Demar white varnish and mix it well with one gallon of turpentine. When the polished surfaces are thoroughly covered with a thin coat, the varnish will scarcely show, but will preserve the polish for years, if it is not scraped off with something very hard.

Vaseline and Blue Ointment: In one pound of vaseline melt 2 ounces of blue ointment—what druggists call one-third—and add, to give it a pleasant odor, a few drops of oil of wintergreen, cinnamon, or sassafras. When thoroughly mixed, pour into a tin can.

Alcohol and Sperm Oil: To make a preservative oil, use high test grain alcohol and best grade of sperm oil, equal parts. Keep in a tightly-corked bottle, and shake well before using, as the alcohol and oil separate after standing. Any moisture on a tool or gun at the time of application is quickly absorbed by the alcohol, which in a short time evaporates, leaving a good coat of sperm oil to protect the surface from rust.

Soda Solution: Rust formation takes place on tools within a few hours after they have been hardened in brine or in any of the numerous hardening solutions containing different salts used for this purpose. To counteract this rusting of tools, they should be boiled in a strong solution of soda water for fifteen or twenty minutes after having been hardened. Sal soda (common washing soda) is the kind to use for the solution. A kettle holding about six or eight gallons of water may be used. About five pounds of soda are put in at the start, and after that about one to one and one-half pounds is added every day. In this way the strength of the solution is kept about right.

The addition of soda is necessary on account of the overflow which is required because of the method used for heating, the solution being brought to the boiling point by introducing steam. The work should always be boiled before being put into the tempering furnace and the latter should be at a temperature of about 212 degrees F., when the tools are changed from the soda kettle to the furnace. A basket arrangement with windlass may be used for raising and lowering the work, to prevent scalding the hands. The direction given, if followed, will prove of advantage in hardening and tempering tools, in that the formation of rust will be prevented.

Oil and Graphite: To prevent screws from getting rusty and sticking tight, instead of using ordinary oil only, add some graphite. After years you will be able to unscrew them with ease, and find them as bright as new, even if they have been exposed to very damp air.

Camphor, Lard and Black Lead: A formula for an anti-rust compound is made as follows: Dissolve 1 ounce of camphor in 1 pound of melted lard; take off the scum, and mix in as much fine black lead as will give it color. Clean the machinery, and smear it with the mixture, and after 24 hours rub clean with a soft linen cloth. The machinery will keep clean, under ordinary circumstances, for a long time.

White Lead and Tallow: In order to keep white lead and tallow soft in winter and summer alike, so that it can be applied with a brush to finished parts of machinery before shipping them, and for use in fitting keys, etc., prepare a mixture composed of five pounds of white lead and fifteen pounds of tallow. Heat this in a suitable receptacle, and stir until the ingredients are thoroughly mixed. Then remove the mixture to a cool place, and add two quarts of linseed oil, continuing to stir the composition until it becomes cold, as otherwise the white lead will settle at the bottom. This mixture will always remain of the same consistency at all temperatures.

Red-lead Paint for Structural Steel: Structural steel is generally protected from rust by painting. A rust-retarding coat of paint may be suitably compounded from red lead mixed with pure linseed oil. The average stock mixture consists of from 25 to 30 pounds of red lead to a gallon of oil. This mixture can be reduced to the proper consistency at the time of application. A small amount of turpentine added to this brush coating will greatly assist in its manipulation, and will also provide for proper penetration. Red lead should be mixed at the time of its application, as it settles quite readily, being an extremely heavy pigment.

Rust Removal. Tools which have become very rusty may be treated with a chemical solution, instead of trying to scour the rust off by means of an abrasive cloth. A good solution for removing rust may be made as follows: Into one quart of distilled water dissolve, little by little, sufficient chloride of tin to obtain a saturated solution, that is, until the water will not dissolve any more of the salts. Put the tool into a receptacle containing the solution and let it stand overnight. In the morning rinse the solution off in running water and dry thoroughly with a piece of chamois or cloth.

Sweet Oil and Lime: A good method for removing rust from steel is to first rub the object with sweet oil, and then, after a day or two, rub it with finely powdered unslaked lime until the rust disappears. Then give it again a coating of oil with a woolen cloth, and put it in a dry place.

Tin Putty, Buckshorn, and Spirits of Wine: A very effective mixture for removing rust from polished surfaces may be made as follows: Ten parts of tin putty (putty-powder or jewelers' putty), 8 parts of prepared buckshorn, and 250 parts of spirits of wine. These ingredients are mixed to a soft paste, and rubbed in on the surface until the rust disappears. When no trace of rust seems to remain, the surface is polished with a dry, soft cloth.

Sulphuric Acid: Rust may be removed from small steel parts such as screws, nuts, pins, etc., when they are not badly pitted,

by dipping them into a dilute solution of sulphuric acid. To prepare the acid bath, pour the acid, little by little, into a bowl partly filled with water. After each addition of acid, try one of the rusted parts, and continue trying until the proper strength is obtained to eat the rust off clean. Let the parts remain in the acid bath until cleaned of rust, then remove and wash in soda water, and then in benzine. Finally, dry the parts and brighten in sawdust.

Muriatic Acid: A quick method of removing rust from steel parts is by rubbing the surface with muriatic acid. A convenient way to do this is to dip a small stick into the acid and rub it over the surface of the work. This procedure is continued for several minutes, dipping the stick in as often as necessary to obtain a sufficient quantity of acid. After this treatment has been completed, the work should be washed with a solution of common washing soda and water and then dried in sawdust.

Removing Rust before Electroplating: A simple method of removing rust from surfaces that are afterwards to be electroplated consists in dipping the articles first into a strong hot potash bath, for about half an hour, and then in a cold muriatic-acid pickling solution, composed of 2 parts of water to 1 of acid. This solution removes the rust in a few minutes, leaving the metal apparently attacked but very little. The previous soaking in the strong hot potash solution is responsible for this rapid pickling, as tests have shown that, without previous dipping, 65 minutes is required by the acid bath, against four minutes when previously treated in the potash bath.

Rust Resistance of Iron and Steel. Silicon in iron increases greatly its tendency to corrode; 0.3 per cent of silicon will make iron rust 20 per cent more rapidly than would ordinary iron free from silicon. On the other hand, alloying steel with nickel or copper gives it increased resistance to corrosion; 0.20 per cent of copper in steel produces a material which is attacked by acids at one-tenth the rate of ordinary iron. The corrosion in the atmosphere is only one-third that of iron free from copper. An increase of copper above 0.20 per cent does not add to the corrosion resisting qualities of the iron.

These results have been obtained not merely by laboratory experiments, but in practice. Roofs have been covered in and around Pittsburg with ordinary sheet steel and also with a sheet steel containing 0.20 per cent of copper. The copper alloy roofs were in good condition when the ordinary sheet iron roofs were completely corroded. These experiments also showed that the metals are less attacked in rural districts than in cities, which, probably, is due to the carbon and acid fumes present in the city atmosphere.

S

Sabin Process. The Sabin process is a method used for coating pipe in order to protect it against moisture. The coating consists of a mixture of asphaltum and linseed oil. After having been dipped in this coating, the pipe is allowed to drain for about half an hour, and is then baked in an oven at a temperature of about 300 degrees F. for two hours.

Saddle. A machine tool saddle is a slide which is mounted upon the ways of a bed, cross-rail, arm, or other guiding surfaces, and the saddle usually supports one or more secondary slides for holding either metal-cutting tools or a work-holding table. On a knee-type milling machine the saddle is that part which slides upon the knee and which supports the work-holding table. The saddle of a planer or boring mill is mounted upon the cross-rail and supports the tool-holding slide. The saddle of a lathe is that part of a carriage which slides directly upon the lathe bed and supports the cross-slide.

Saddle Key. This form of key has parallel sides and is curved on its under side to fit the shaft. It is slightly tapered on top so that, when it is driven tightly in place, the shaft is held by frictional resistance. This key should be fitted so that it bears lightly on the sides and heavily between the shaft and hub throughout its entire length. As the drive with this type of key is not positive, it is only used where there is little power to transmit. It is an inexpensive method of keying, as the shaft does not need to be machined.

S.A.E. Standard Screw Thread. The screw thread standard of the Society of Automotive Engineers (S.A.E.) is intended for use in the automotive industries of the United States. The S.A.E. Standard includes a Coarse series, a Fine series, an 8-thread series, a 12-thread series, a 16-thread series, an Extra-fine series, and a Special-pitch series. The Coarse and Fine series, and also the 8-, 12- and 16-thread series, are exactly the same as corresponding series in the American Standard. The Extra-fine and Special-pitch series are S.A.E. Standards only.

The American Standard thread *form* (or the form previously known as the U. S. Standard) is applied to all S.A.E. Standard screw threads. The Extra-fine series has a total of six pitches ranging from 32 down to 16 threads per inch. The 16 threads per inch in the Extra-fine series, applies to all diameters from 1¾ up to 6 inches. This Extra-fine series is intended for use on

relatively light sections; on parts requiring fine adjustment; where jar and vibration are important factors; when the thickness of a threaded section is relatively small as in tubing, and where assembly is made without the use of wrenches.

The S.A.E. Special pitches include some which are finer than any in the Extra-fine series. The special pitches apply to a range of diameters extending from No. 10 (0.1900 inch) up to 6 inches. Each diameter has a range of pitches varying from five to eight. For example, a ¼-inch diameter has six pitches ranging from 24 to 56 threads per inch, whereas a 6-inch diameter has eight pitches ranging from 4 to 16 threads per inch. These various S.A.E. Standard series are intended to provide adequate screw thread specifications for all uses in the automotive industries.

S.A.E. Steel. This abbreviated term means that the steel is one of the standard compositions approved by the Society of Automotive Engineers, Inc. A system of numbering is used to indicate the general class of steel and the approximate percentages of the chief elements.

Safety Coupling. A safety coupling is a coupling so arranged that, if the power to be transmitted exceeds the normal requirements, the driven member will be permitted to slip.

Salt Baths for Heat-Treating Operations. Molten baths of various salt mixtures or compounds are used extensively for heat-treating operations such as hardening and tempering; they are also utilized for annealing ferrous and non-ferrous metals. Commercial salt-bath mixtures are available which meet a wide range of temperature and other metallurgical requirements. For example, there are neutral baths for heating tool and die steels without carburizing the surfaces; baths for carburizing the surfaces of low-carbon steel parts; baths adapted for the usual tempering temperatures of, say, 300 to 1100 degrees F.; and baths which may be heated to temperatures up to approximately 2400 degrees F. for hardening high-speed steels. Salt baths are also adapted for local or selective hardening, the type of bath being selected to suit the requirements. For example, a neutral bath may be used for annealing the ends of tubing or other parts, or an activated cyanide bath for carburizing the ends of shafts or other parts. Surfaces which are not to be carburized are protected by copper plating. When the work is immersed, the unplated parts are subjected to the carburizing action.

Baths may consist of a mixture of sodium, potassium, barium, and calcium chlorides or nitrates of sodium, potassium, barium. and calcium in varying proportions, to which sodium carbonate and sodium cyanide are sometimes added to prevent decarburization. Various proportions of these salts provide baths of different

properties. The specific gravity of a salt bath is not as high as that of a lead bath; consequently, the work may be suspended in a salt bath and does not have to be held below the surface as in a lead bath.

Sand Blasting. The foundry sand-blast was developed for the cleaning of castings, and its advantages for cleaning or surfacing in many branches of metal working, plating, and finishing have been so fully demonstrated, that it has become an important process in different lines of manufacture. Thoroughly sand-blasted castings can be machined more rapidly and at reduced expense. In sand-blasting, sand or some other abrasive is forced through a nozzle, under pressure, against the surface to be treated. The sand-blast machine may have single or multiple nozzles, the size of each opening, together with the pressure maintained, governing the air volume required. The sand-blasting process is used, not only in cleaning iron and steel castings, but also for brass and aluminum, when the pressure and nozzles are properly adapted to these softer materials. Sheet-metal parts are frequently prepared for plating, galvanizing, enameling, or painting by sand-blasting. The process is also employed for matt-surfacing metals, roughing handles of instruments, lettering or frosting glass, lettering marble, blasting wood for the purpose of bringing out the grain, and many other uses too numerous to mention here.

Air, compressed to varying pressures, is commonly employed in all sand-blasting equipments, but the pressure is applied in different ways. The three systems in use are generally designated as the direct-pressure system, the suction or syphon system, and the gravity system. In the direct-pressure system the air and the abrasive are combined in and discharged from a closed tank through a nozzle. In the suction system, the abrasive is carried to the nozzle by a suction created by a jet of compressed air, which, in passing through the nozzle, carries the abrasive with it. In the gravity system, the abrasive is carried by mechanical means to a place above the nozzle and is fed down by gravity. At the nozzle, the abrasive and compressed air combine and are discharged. For some classes of work a small nozzle opening, that is, a fine strong jet, may be desirable; for other work a broader stream, covering a larger surface but working at a lower pressure may be best. The pressure that should be used depends upon the nature of the work. The following figures will give an idea of the pressures generally used. For cleaning light castings, such as stove castings, etc., use from 5 to 10 pounds; for medium- and heavy-grade iron castings, from 15 to 20 pounds; for steel castings, from 30 to 75 pounds; for buildings and steel structures, from 5 to 30 pounds, depending upon the height.

Sand-Blasting Abrasives. Sand is the most commonly used abrasive for sand-blasting on account of its relatively low price. Ordinary lake or river sand is inferior to sea sand and silica sand, as the two latter possess greater hardness and are therefore more lasting. River sand results in more or less dust, and it disintegrates rapidly. Abrasives such as steel grit and shot are used to a certain extent, and the use of these more expensive abrasives is warranted under certain conditions. For classes of work such as electroplating or galvanizing, the metallic dust adhering to the work would make its use prohibitive, because it prevents perfect galvanizing, although no difficulty is experienced in this respect with sand. There is no one abrasive that is best adapted to all classes of work. A selection must be made with due regard to reclaiming means, to greatest economy in operation, and to maximum production. All abrasives should be screened each time before using, to remove particles large enough to clog the nozzle, and also to eliminate fine particles which only produce dust and have no abrasive quality, but which consume some of the pressure. Screen separators, frequently operated by compressed air, may be used for this purpose.

Sand-Blast Abrasive Screens. In reference to screens for sand-blast abrasives, the number of the mesh gives the number of openings to the linear inch. For example, No. 10 mesh means that there are ten openings or meshes to the inch, or one hundred openings to the square inch. Ocean sands, which are largely used in the eastern states, would be graded about as follows:

Sand No.	Passes Screen	Remains on Screen
1	20 mesh	40 mesh
2	14 mesh	20 mesh
3	8 mesh	14 mesh
4	5 mesh	8 mesh

The weight of the wire used for the screens is governed by the weight and character of the material to be screened, so that the size or gage of the wire often varies for the same number of screen, and this, in turn, somewhat determines the size of the openings or meshes. The nature of the sand-blast apparatus is such that precise grading is not necessary.

Sand-Buffing. See Buffing.

Sand-Hole. In a casting, a sand-hole is a section of the casting in which sand has been entrapped. The sand is eroded from the mold by the entering current of molten iron and floats to the top, but the iron may have been partially solidified before the sand reaches the top, and as a result it will remain imprisoned in

the body of the casting. Occasionally large cavities are formed in this way which impair the strength of the casting.

Sanding Machine. These are wood-working machines and they are made in two general types: The revolving disk or face plate type and the traveling belt type. Both are faced with sand paper or other abrasive material. The stock is smoothed by bringing it in contact with the working surface. The disk machine is the one usually found in the pattern shops.

Sand, Molding. See Molding Sand.

Saponification Value of Oil. The saponification value of an oil is the number of milligrams of caustic potash required to completely saponify one gram of the fat or oil. A low saponification value generally indicates adulteration with mineral oil.

Saturated Air. See Air, Saturated.

Saybolt Viscosimeter. The Saybolt Universal Viscosimeter is in general use in the United States for testing the viscosity of lubricating oils. It consists of an oil tube surrounded by a bath for temperature control. There is an overflow cup at the top of the tube and a small outlet near the bottom. An enlarged section just below the outlet tube is closed with a cork or stopper which is withdrawn at the instant the test is started. The surrounding bath is equipped with means for heating or cooling to one of the standard testing temperatures of 70, 100, 130 or 210 degrees F. Below the outlet, there is a glass receiving flask of standard form and size. This has a capacity up to its graduation mark of 60 ml (milliliters) at 68 degrees F. The Saybolt viscosity at the testing temperature is indicated by the time in seconds required to fill this receiving flask up to the graduation mark, assuming that the test is conducted according to a standard procedure. The Saybolt Furol Viscosimeter is used for fuel and road oils.

Scabbiness. Scabbiness is a defect on the surface of castings caused by the erosive action of the molten metal on the mold, the iron eating away fillets or partitions or scouring away patches of sand as it flows into the mold. As a result, the casting will not be of the proper form, but will have its angles partly filled up and unsightly projections on its surface.

Scale Annealing Furnace. This is a type of furnace used in connection with the cold-rolling of sheet metal, in which the coils of sheet steel are exposed to the action of an oxidizing atmosphere while being heated. This method of annealing is only employed in the case of steel which has been decarburized on the surface, and the "scale anneal" serves to remove the decarburized metal.

Scale, Boiler. See Boiler Scale.

Scale in Mechanical Drawing. The term "scale" is applied (1) to the graduated rule or instrument used in measuring linear dimensions and (2) the "scale of a drawing" indicates its size relative to the actual size as, for example, when the scale of the drawing is such that 3 inches on the drawing is equivalent to an actual dimension of one foot. The scales or measuring instruments used by draftsmen have two general classes of graduations. The first consists of regular standard graduations for "full size" drawings, which are drawings made the same size as the actual parts they represent; the second covers graduations that are adapted for drawings made on a scale much smaller than the parts represented. In the first class, the inches may be divided into eighths, sixteenths, thirty-seconds, and sixty-fourths, or in tenths and hundredths; in the second class, the main graduations represent feet, and one foot on these reduced scales may actually measure 1½ inches, 3 inches, or some other fractional part of a foot.

How to Use a Draftsman's Scale: When drawings are made full-size, a scale is used which is graduated in inches and subdivisions of an inch, in the usual manner. This scale is also used for half-size drawings or those drawn to a scale of 6 inches = 1 foot. The half-inch divisions on the scale are then considered the same as inches, and the sixteenth divisions correspond to eighths of an inch on the half-size drawing. If a half-size drawing is too large to go on a standard sheet and a still greater reduction of size is required, then a scale having special graduations is used. The reduced scales generally used on mechanical drawings are as follows:

Scale of 6 inches = 1 foot (½ size)
Scale of 3 inches = 1 foot (¼ size)
Scale of 1½ inches = 1 foot (⅛ size)
Scale of 1 inch = 1 foot (1/12 size)
Scale of ¾ inch = 1 foot (1/16 size)

A draftsman's scale has one or more of these reduced graduations, representing some reduced scale such as ¾, 1½, or 3 inches to the foot. The method of reading and using one of these scales will be explained by considering the scale of 3 inches to the foot. A length of 3 inches along one edge of the measuring scale is divided into twelve equal parts representing inches and each of these inch divisions is further divided into eighths. This 3-inch section of the scale is considered the same as though it were 1 foot long, since it represents a length of 1 foot on the reduced scale of the drawing. See also Drawing Sizes.

Scale Sensibility. The quality of accuracy in a weighing scale is not alone sufficient to insure its suitability for a given purpose. It must also have a proper sensibility. The sensibility of a scale or of any engineering instrument is its ability to respond to small variations in the quantity which it is to measure. It is usually expressed in terms of the distance or angle traversed by the pointer or other reading or indicating device for a unit change in the quantity being measured. In a weighing-scale, it is found convenient and advantageous for a number of reasons to invert the ratio and use the term "sensibility reciprocal." In scales provided with a beam and trig-loop, the sensibility reciprocal is the weight required to be placed upon the platform to turn the beam from a horizontal position of equilibrium in the middle of the trig-loop to a position of equilibrium at the top of the loop. The sensibility reciprocal may be determined by subtracting the weight instead of adding it, thereby causing the beam to assume a position of equilibrium at the bottom of the loop; or, indirectly, by moving the sliding poise on the beam the required amount in either direction, to obtain the specified change in the position of equilibrium of the beam; or by adding or subtracting small weights to or from the counterpoise until the specified change is obtained, and determining the equivalent of the small weights used, in terms of weight on the platform.

The sensibility and accuracy of scales are often confused, as the user is likely to assume that a scale which responds readily to slight changes of load is an accurate scale. The sensibility of a scale is not directly a measure of its accuracy. It indicates only to what degree of precision readings may be taken, provided proper allowance be made for the error or correction of the scale at that reading, the effect of friction being considered eliminated.

Scalping of Crucibles. Although crucibles are free from moisture when removed from the kiln, they rapidly absorb it, and many take up 5 per cent of moisture during shipment from maker to user. If, instead of eliminating the moisture by a gradual annealing, the damp crucible is put directly into a hot furnace, or into a cold one and heated too rapidly, the moisture will be changed into steam so that the steam evolved will blow pieces of the crucible off bodily; that is, the crucible will "scalp." To prevent this, it must be raised very gradually from room temperature to a temperature somewhat above the boiling point of water, so that the moisture may be slowly driven off without "scalping."

Schedule Numbers for Pipe. See Pipe Schedule Numbers.

Schiele Curve. Same as Tractrix.

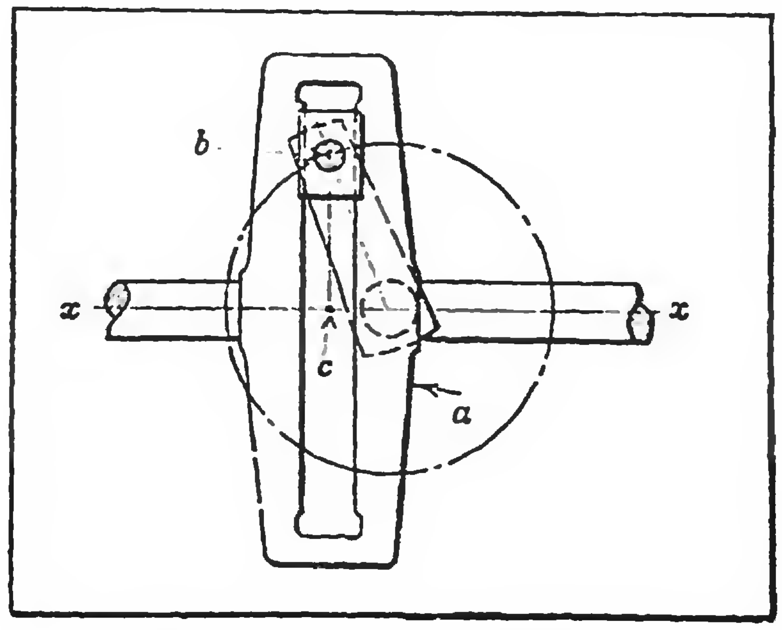
Scientific Management. In general, scientific management aims to correlate and systematize all the best modern methods and developments in factory administration and work, and to adhere strictly to the results of investigations carried out in a scientific manner. Management under this system is not content to rely upon records or upon the judgment of the most experienced workmen, but brings to its aid all the resources of scientific investigation. Methods of performing work are carefully analyzed, and the best elements of all of these combined in order to develop a new method. Having established the best methods, workmen under scientific management are instructed in regard to approved methods of working, and some incentive or reward is offered for carrying out the work in the prescribed manner.

Sclerometer. The Turner sclerometer is an instrument for testing hardness, which is adapted primarily for laboratory use. A diamond point is used to scratch a line on the work under a known pressure, after which the width of this line is read and converted into arbitrary figures. The work must have a bright surface to facilitate reading. The operation is slow, but this method allows minute laboratory studies to be made.

Scleroscope. The scleroscope is an instrument which measures the hardness of the work in arbitrary terms of elasticity. A diamond-tipped hammer is allowed to drop from a known height on the metal to be tested. As this hammer strikes the metal, it rebounds, and the harder the metal, the greater the rebound. The extreme height of the rebound is noted, or with the latest type of machine, recorded, and an average of a number of readings taken on a single piece will give a good indication of the hardness of the work. The surface smoothness of the work affects the reading of the instrument, and between a filed surface and a surface on the same work polished there may be a difference of ten points. The readings are also affected by the contour and mass of the work and the depth of the case, in carburized work, the soft core of light-depth carburizing, pack-hardening, or cyanide hardening, absorbing the force of the hammer fall and decreasing the rebound.

Dial Type: This improved type of instrument is provided with a dial, the hand of which remains fixed an indefinite length of time after making a test, instead of obtaining a momentary reading as with the older design of scleroscope. The hammer differs from that of the earlier models in that it is longer, heavier, and drops and rebounds a comparatively short distance. The hardness values obtained with this instrument agree with those indicated by the vertical scale of the older design.

Scotch Yoke. The irregularity in the motion of a cross-head of an engine relative to its crank in the simple form of crank mechanism, which irregularity is due to the fact that one-half of the crankpin circle curves toward the cross-head, whereas the other half curves away from it, has an important effect on the design of steam-engine valve-gears, and it is objectionable in some types of mechanism. A simple form of mechanism for eliminating the irregularity of cross-head motion is known as a "crank and slotted cross-head" or the *Scotch yoke.* The cross-head *a* (see diagram) has a slot which is at right angles to the center-line *xx* representing the direction of rectilinear movement. The crankpin carries a block, which is a sliding fit in this slot, and is free to revolve about the pin. As the crank revolves, the distance which the crankpin moves, as measured in a horizontal direction, will be the same as the movement of the cross-head. This mechanism is sometimes called a *harmonic motion,* because if the crank rotates uniformly, the cross-head will be given a harmonic motion. When a point, as at *b*, moves with uniform velocity along a circular path, point *c* will have a harmonic motion along the center-line *xx*.

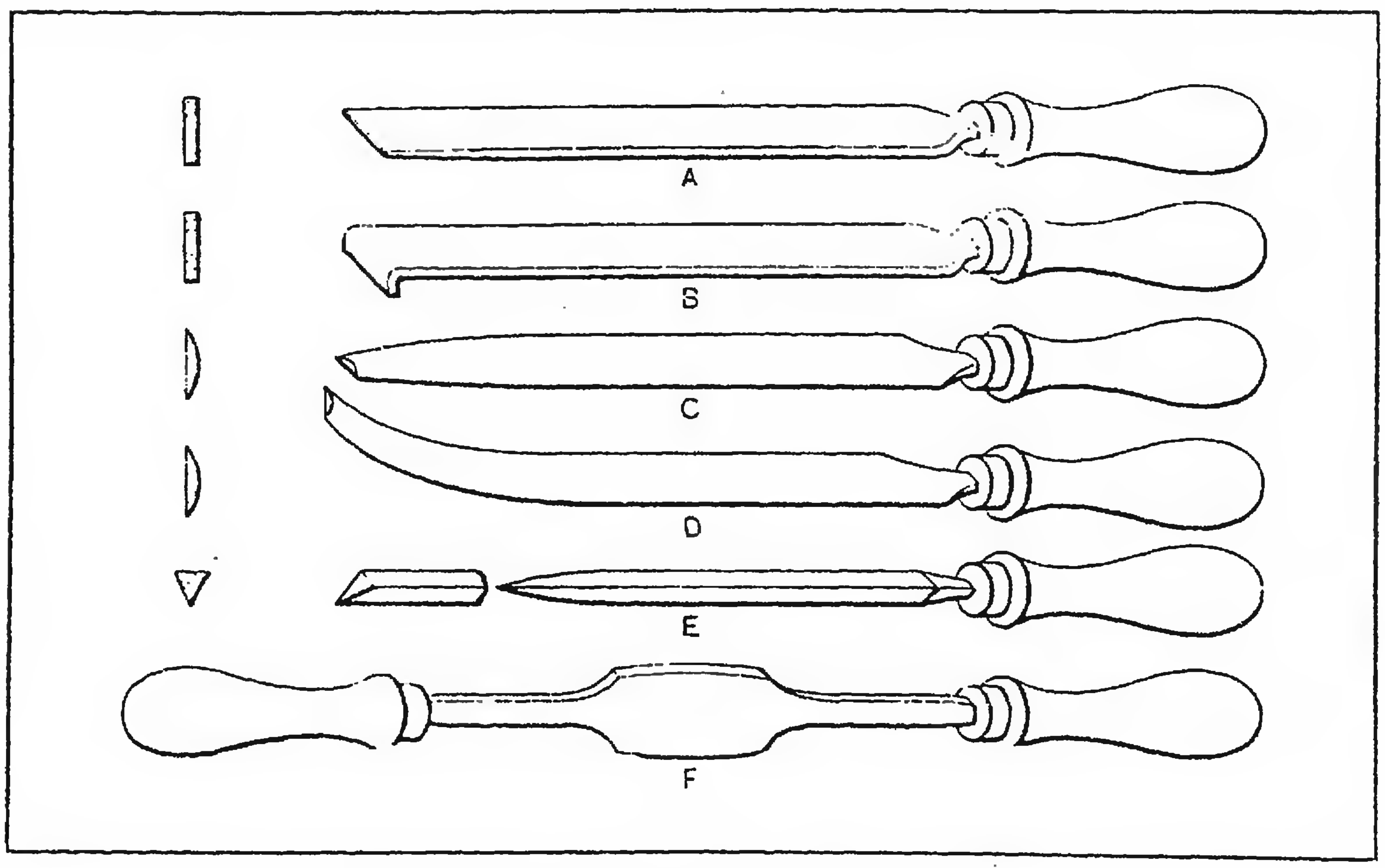


Scotch Yoke or Slotted Cross-head

Scraping Machine Parts. In metal working, slight errors in plane or curved surfaces are often corrected by the use of hand scrapers; scraping is also employed to produce ornamental effects on exposed surfaces. For correcting errors, the part to be scraped is ordinarily applied to whatever surface it is being fitted; the bearing marks or "high spots" are then noted and removed by scraping. By repeatedly obtaining these bearing marks and then removing them, a more evenly distributed bearing is secured. In this way, bearing boxes are often fitted to their shafts after having been bored. Small flat surfaces are scraped to make them more accurate, the method being to first apply the work to a standard surface plate, note the bearing marks and, if there is unevenness, correct the error by scraping. In fitting two flat parts together, it is common practice to first scrape one member to secure as true a surface as possible, and then use it as a standard while fitting the other part. In order to make the bearing marks show clearly, some kind of red or black marking ma-

terial is generally used. A thin coating is applied to the bearing shaft, surface plate, or whatever surface the work is to be scraped to fit. The work is then rubbed over this surface and the marking material shows just where the high spots are. It is important to keep the marking material in a covered box in order to exclude all grit or chips. The scraper should be made "glass hard" and be given a fine edge by the use of an oilstone. The materials commonly used to show the bearing marks are oil mixed with lampblack, Prussian blue, or red lead.

Scrapers: The different forms of scrapers commonly used in fitting machine parts, etc., are shown by the accompanying illustration. The *flat scraper A* is almost invariably used for plane surfaces. For ordinary purposes, the scraper blade is about 3/16 inch thick, from 1 to 1¼ inches wide, and is drawn out at the point to a thickness of about 1/16 inch. The cutting end is as hard as possible and is rounded slightly, in grinding, so that the outer corners will not score the surface being scraped. The grinding should be done, preferably, on a wet grindstone, the edge being finished with an oilstone. The *hook scraper B* is also used on flat surfaces. It is preferred by some workmen for obtaining a fine, smooth surface and can be used, occasionally, in narrow spaces where there would not be room enough for a



Different Forms of Hand Scrapers

straight, flat scraper. Straight and curved scrapers of the "half-round" type are shown at *C* and *D*. These are used for scraping bearings, etc., the sides forming the cutting edges. The curved type *D* is more convenient to use on large half-bearings, as it is

held at an angle and the scraping is done by the curved edge. The *three-cornered* or *three-square scraper* shown at *E* is also used to some extent on curved surfaces. When the end is beveled, as shown in the detail view to the left, this form of scraper is convenient for producing sharp corners or for "relieving" them slightly. The *two-handled scraper* shown at *F* is an excellent form for scraping bearing boxes and all curved surfaces which are so located that this type can be used. This style of scraper is much superior to the form shown at *C* and *D*, especially for large work. The straight or curved half-round type works very well on soft bearing metals such as babbitt metal, but on brass or bronze, it cuts slowly and, as soon as the edge is slightly dulled, considerable downward pressure is necessary. The type *F* requires very much less effort on the part of the workman, and it will cut rapidly. As there are two handles instead of a single handle at one end, the blade can be pressed against the work with little exertion. This form of scraper is largely used for the heavy scraping required in fitting large connecting-rod brasses, etc. The sides are sometimes ground slightly concave (to give the cutting edges "rake") by holding them against the face of the grinding wheel.

Spotter: Flat finished surfaces on the ways of machine tools, etc., are often finished by spotting, frosting or flaking, partly to obtain an ornamental appearance and also because the spotted surface holds lubricant more effectively. One type of spotter placed on the market is so arranged that the scraper, as it is pushed across a guide placed upon the work, receives a rocking motion so that the blade produces a uniform half-moon effect without skill or experience on the part of the workman. By adjusting a small thumb screw, different shaped spots may be obtained.

Scraping, Power. For scraping flat surfaces on machine tools to an accurate bearing, a power scraper is efficient. The scraper tool of a design on the market is mounted on an arm, and a reciprocating movement is imparted to it by a rack and pinion drive. The motor is coupled to the scraper tool through gears and clutches in such a manner that when the operator pushes a control sleeve forward, the scraper tool is driven forward. When the operator pulls the sleeve backward at the end of the forward stroke, a reverse drive is engaged to pull the tool back. With this arrangement, the scraper is operated in the same manner as a hand tool, except that no manual effort is required. With the sleeve held forward or back, any desired length of stroke may be imparted to the scraper tool. The forward stroke is at the rate of 60 feet per minute, and the return stroke at the rate

of 90 feet per minute. With the sleeve in the neutral position, the drive is disengaged and the scraper arm can be pulled forward or pushed back over a range of 5 feet, in order to bring the tool into the required position. With a machine of this type, it is possible to scrape faster than by hand, and the fatigue factor is entirely eliminated. The arm on which the scraper tool is mounted can be instantly pushed or pulled the length of 5 feet. There is also a power-driven screw, engaged by means of a hand-lever, which provides for raising or lowering the head to bring the tool to the most convenient angle for scraping. A ball-bearing swivel on the column permits the tool to be easily swung around a complete circle.

Scrap Value. The scrap value of a machine is the actual cash return brought by the sale of the materials (iron, copper, etc.) of which the machine is made, at current market prices, less cost of junking. The cost of junking will be high in the case of large and unwieldy machines, and, in some cases, will offset the return from the sale of scrap, making the net scrap value zero or even a negative quantity.

Screw. A screw may be defined as a cylinder around which a thread is wound in successive coils or helices, all turns being equally spaced. The lead of a single-threaded screw is the distance between like points on successive threads measured on a line parallel to the axis of the screw. The amount that a screw advances in one turn is equal to the lead, and in fractional turns it is equal to the same fraction of the lead; thus, if a screw is given one-fourth turn, it advances one-fourth of the lead. Considered as a machine element, the screw is classed as one of the "mechanical powers." In the case of the screw, the initial force, tending to turn it, moves through the circumference of a circle, the point of application usually being at the end of a crank or bar, at the surface of a pulley or handwheel. Hence, the applied force multiplied by the circumference of the circle described by the force equals the resistance multiplied by the lead.

Screw Brake. This is an automatic mechanical brake used largely on overhead traveling cranes. It is so arranged that when lifting the load the whole brake revolves without resistance, but as soon as the lifting effort ceases and a slight reverse has taken place, the load is held securely by friction. In order to lower the load, the motor must be reversed, thus reducing the pressure on the friction faces and allowing the load to slip steadily.

Screw Conveyors. The screw or worm conveyor is one of the oldest types. Screw conveyors are built up of sectional screw flights, that are fixed to a central shaft or spindle by means of

a shank, which is tapped and fitted with a nut. The spindle is usually made of pipe in lengths of about 8 feet, the different lengths being coupled together. The continuous screw conveyor consists of a spindle and screw all rolled in one continuous screw into sections of about 10 feet. Screw conveyors are fitted into a trough, so as to leave a clearance of between 1/8 and 1/4 inch. Too long a run should not be used for the conveyor without "breaking in" for a drive—say, not over 200 feet for a 6-inch screw, and not over 300 feet for a 9-inch screw conveyor. If possible, the drive should always be placed so as to pull the material toward the drive instead of pushing the material away from the drive.

Screw-Driving Machine. For driving either wood screws or machine screws in large numbers, a power-driven automatic screw-driving machine is efficient. In the operation of the Reynolds machine the screws are thrown at random into a magazine from which they are delivered through an inclined chute to the lower end of the spindle, in the proper position for driving. As the spindle is lowered by operating a foot lever, a screw driver bit in the spindle engages the screw lost and drives the screw with great rapidity.

Screw Machines and Turret Lathes. When a machine is referred to as a turret lathe, this is generally understood to be a horizontal machine designed either for handling bar stock, chuck work, or both for bar and chuck work, and the turret may or may not have a power-feeding movement. A turret lathe that is designed more particularly for turning comparatively small screws, pins, etc., from steel rods or bar stock, is commonly (although not invariably) known as a *hand screw machine,* or as a *turret screw machine.* According to the practice of some manufacturers, the name screw machine is applied to small turret lathes which have a collet chuck in the spindle and a "wire feed" or a mechanism for feeding a wire rod or bar stock through the spindle. When the machine is intended for either bar or chuck work, or for chuck work exclusively, the name turret lathe is commonly used, and such a machine may or may not have a stock-feeding mechanism which operates in conjunction with the spindle chuck. The foregoing method of distinguishing between the two types, however, is not universal, and there is no general agreement in the use of these names. See also Automatic Screw Machine.

Screw Machine Taps. The taps known in the tap manufacturing business as *screw machine taps* are, as the name indicates, used for tapping in automatic screw machines. The thread to be cut is usually short and the taps, therefore, are essentially

different from other taps used for nut tapping in machines. The chamfered end of the thread of these taps is usually very short, as in most cases the tap is required to tap down to the bottom of a hole. The thread is relieved only on the top of the thread of the chamfered portion.

Screw Pitch Gage. This type of gage is used for determining the number of threads per inch on a screw, and consists of a holder which has pivoted at each end a number of leaves that are notched to conform to different thread pitches, the number of threads being stamped upon each leaf.

Screw Pump. The screw pump is a special form of the rotary type. One design has two parallel shafts and on each shaft there are right- and left-hand screws of coarse pitch so arranged that the threads of one screw mesh with the thread groove of the screw on the opposite shaft. These screws fit closely into the pump casing or cylinder. When the pump is in operation, the liquid flows from the suction pipe to the two ends of the cylinder and is forced toward the center by the action of the two pairs of intermeshing threads, the discharge being at the center and on the opposite side from the suction opening.

Screws, Collar-Head. See Collar-head Screws.

Screw, Self-Tapping. See Self-tapping Screw.

Screws, Multiple. Considerable confusion is often caused by indefinite designation of multiple-thread (double, triple, quadruple, etc.) screws. One way of expressing that a double-thread screw is required is to say, for instance: "3 threads per inch double," which means that the screw has 3 *double* threads, or 6 threads per inch, counting the threads by a scale placed alongside of the screw. The pitch of this screw is 1/6 inch, and the lead twice this, or 1/3 inch. To cut this screw, the lathe will be geared to cut 3 threads per inch, but the thread will be cut only to the depth required for 6 threads per inch. "Four threads per inch triple" means that there are 4 times 3, or 12 threads along one inch of the screw, when counted by a scale; the pitch of the screw is 1/12 inch, but, being a triple screw, the lead of the thread is 3 times the pitch, or ¼ inch. The best way of expressing that a multiple-thread screw is to be cut, when the lead and the pitch have been figured, is, for example: "¼ inch lead, 1/12 inch pitch, triple thread."

Screws, Power Transmission. The square form of thread has a somewhat higher efficiency than threads with sloping sides, although when the angle of the thread form is comparatively

small, as in the case of an Acme thread, there is little increase in frictional losses. The Acme thread has superseded the square form on many classes of equipment requiring lead-screws or other power transmitting screws, because the former has practical advantages in regard to cutting and also in compensating for wear between the screw and nut. Multiple-thread screws are much more efficient than single-thread screws, as the efficiency is affected by the helix angle of the thread. The notation which follows applies to the formulas in the next paragraph. F = force applied at end of lever-arm; L = load moved by screw; R = length of lever-arm; l = lead of screw thread; r = mean or pitch radius of screw; μ = coefficient of friction.

Force Required to Turn Screw: In determining the force which must be applied at the end of a given lever-arm in order to turn a screw (or nut surrounding it), there are two conditions to be considered: (1) When rotation is such that the load *resists* the movement of the screw, as in raising a load with a screw jack; (2) when rotation is such that the load *assists* the movement of the screw, as in lowering a load.

When the motion is opposite the thrust of the load which *resists* the screw movement:

$$F = L \times \frac{l + 2\,r\,3.1416\,\mu}{2\,r\,3.1416 - \mu l} \times \frac{r}{R}$$

When the motion is in the same direction as the thrust of the load which *assists* the screw movement:

$$F = L \times \frac{2\,r\,3.1416\,\mu - l}{2\,r\,3.1416 + \mu l} \times \frac{r}{R}$$

If lead l is large in proportion to the diameter so that the helix angle is large, F will have a negative value, which indicates that the screw will turn due to the load alone, unless prevented by a force F which is great enough to prevent rotation of a non-locking screw.

Coefficients of Friction: According to experiments by Professor Kingsbury made with square-threaded screws, a coefficient of 0.10 is about right for pressures less than 3000 pounds per square inch and velocities above 50 feet per minute, assuming that fair lubrication is maintained. If the pressures vary from 3000 to 10,000 pounds per square inch, a coefficient of 0.15 is recommended for low velocities. The coefficient of friction varies according to lubrication and the materials used for the screw and nut. For pressures of 3000 pounds per square inch and using heavy machinery oil as a lubricant, the coefficients were as follows: Mild steel screw and cast-iron nut, 0.132; mild steel nut, 0.147; cast brass nut, 0.127. For pressures of 10,000 pounds per

square inch using a mild steel screw, the coefficients were, for a cast-iron nut, 0.136; for a mild steel nut, 0.141; for a cast brass nut, 0.136. For dry screws, the coefficient may be 0.3 to 0.4 or higher.

Coefficient of Friction for Angular Thread Forms: Frictional resistance is proportional to the normal pressure, and for a thread of angular form, the increase in the coefficient of friction is equivalent practically to μ sec β, in which β equals one-half the included thread angle; hence, for a U. S. Standard thread, a coefficient of 1.155 μ may be used.

Effect of Helix Angle on Efficiency: The efficiency between a screw and nut increases quite rapidly for helix angles up to 10 or 15 degrees (measured from a plane perpendicular to the screw axis). The efficiency remains nearly constant for angles between about 25 and 65 degrees, and the angle of maximum efficiency is between 40 and 50 degrees. A screw will not be self-locking if the efficiency exceeds 50 per cent. For example, the screw of a jack or other lifting or hoisting appliance would turn under the action of the load if the efficiency were over 50 per cent. It is evident that maximum efficiency for power transmission screws often is impracticable, as for example, when the smaller helix angles are required to permit moving a given load by the application of a smaller force or turning moment than would be needed for a multiple screw thread.

Efficiency Formula: In determining the efficiency of a screw and a nut, the helix angle of the thread and the coefficient of friction are the important factors. If E equals the efficiency, A equals the helix angle, measured from a plane perpendicular to the screw axis, and μ equals the coefficient of friction between the screw thread and nut, then the efficiency may be determined by the following formula, which does not take into account any additional friction losses, such as may occur between a thrust collar and its bearing surfaces:

$$E = \frac{\tan A\ (1 - \mu \tan A)}{\tan A + \mu}$$

This formula would be suitable for a screw having ball-bearing thrust collars. Where collar friction should be taken into account, a fair approximation may be obtained by changing the denominator of the foregoing formula to tan $A + 2\mu$. Otherwise the formula remains the same.

Screw Stock. The composition of ordinary screw stock should be, in general, about as follows: Carbon, from 0.08 to 0.20 per cent; manganese, 0.30 to 0.80 per cent; phosphorus, not to exceed 0.12 per cent; sulphur, 0.06 to 0.12 per cent. Screw stock is easily machined and cheap, but lacks strength and toughness and is not safe for vital parts. Screws made from hot-

rolled bars of this material should be heat-treated and not used in an annealed condition. Screws made from cold-rolled bars are much stronger.

S.A.E. 1111: This steel is made by the Bessemer process and is often called screw stock. It is of excellent machining properties, but has an unfavorable property of cold shortness; hence, should not be used for vital parts. In the cold-drawn or cold-rolled condition, it has excellent strength, being nearly equal to No. 1030 in the sizes below 1 inch. It may be carburized and cyanided, but open-hearth steels are recommended when heat-treating is necessary. This steel is used for studs, screws, and automatic machine products.

S.A.E. 1112 (old No. × 1112): This is a higher sulphur type of Bessemer steel than No. 1111 and there is an improvement in machinability.

S.A.E. No. 1113: The highest sulphur variant of Bessemer screw steel in which sulphur is added to improve finish and machinability. This steel is used where production, speed and finish are paramount. It should not be used for vital parts, and heat-treatments are not recommended.

S.A.E. 1115: This steel is commonly known in the trade as "open-hearth screw stock." It is somewhat inferior to Bessemer steel in machining properties, but possesses a decidedly better combination of strength and toughness and is more dependable for use in casehardened parts and for such operations as bending, swaging, riveting, and forming.

Screw-Thread Comparator. The Hartness screw-thread comparator is a projection type of apparatus designed to show the magnitude and kind of errors in screw threads. When the thread shadow is projected upon the standard tolerance chart, the relative positions of the shadow and chart not only show the resultant effect of lead errors, the pitch diameter, the finish and form of the thread, but also whether the tolerance is within the limits that are required in interchangeable manufacture.

Screw Threads. Different screw-thread forms and standards have been originated and adopted at various times, either because they were considered superior to other forms or because of the special requirements of screws used on a certain class of work. Some of the more important and desirable features of a screw thread are as follows: 1. The thread should be of such a shape that the tool for producing it can be easily made. 2. The cutting edges of the tool should not be so pointed or delicate that they are easily worn away by the cutting action. 3. It should be possible to test the diameter and form of the thread with a minimum of measuring and gaging. 4. The form should be such that a good bearing between a screw and nut may be obtained without un-

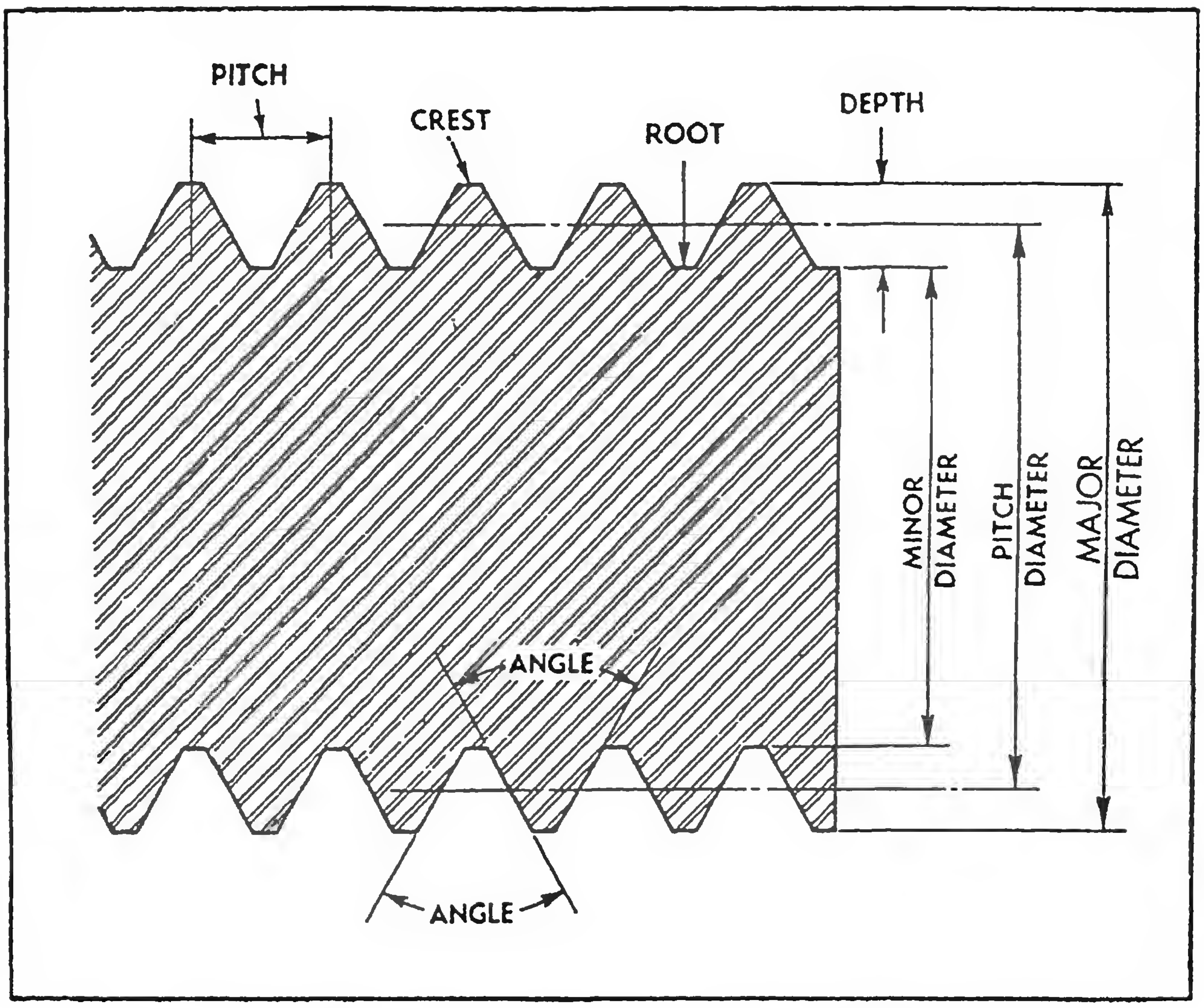


Diagram Illustrating Meaning of Terms Applied to Screw Threads

necessary care and refinement in cutting and measuring. 5. The angles of the sides should be as acute as is consistent with the required strength, because the greater the angle, the greater the friction between the threads of a bolt and nut and also the greater the force tending to burst the nut.

For information about different standard threads and thread forms, refer to name of thread or standard. See Acme Thread; American Standard Screw Thread System; British Association Thread; British Standard Fine Screw Thread; Dardelet Thread; French Thread (S.F.); Harvey Grip Thread; Lowenherz Thread; Pipe Thread; S.A.E. Standard Screw Thread; Unified Screw Threads; V-thread; Whitworth Standard Thread; Worm Thread.

Screw Thread Definitions. The definitions which follow include only the more important terms. See also accompanying illustration.

Major Diameter: The largest diameter of a screw thread. The term major diameter applies to both internal and external threads and replaces the term "outside diameter" as applied to the thread of a screw and also the term "full diameter" as applied to the thread of a nut.

Minor Diameter: The smallest diameter of a screw thread. The term minor diameter applies to both internal and external threads and replaces the terms "core diameter" and "root diameter" as applied to the thread of a screw and also the term "inside diameter" as applied to the thread of a nut.

Pitch Diameter: The diameter of an imaginary cylinder the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces cut by the surface of the cylinder.

Pitch: The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis

Lead: The distance a screw thread advances axially in one turn. On a single-thread screw, the lead and pitch are identical; on a double-thread screw, the lead is twice the pitch; on a triple-thread screw, the lead is three times the pitch, etc.

Angle of Thread: The angle included between the sides of the thread measured in an axial plane.

Helix Angle: The angle made by the helix of the thread at the pitch diameter with a plane perpendicular to the axis.

Crest: The top surface joining the two sides of a thread.

Root: The bottom surface joining the sides of two adjacent threads.

Depth of Thread: The distance between the crest and the root of thread measured normal to the axis.

Depth of Engagement: The depth of thread contact of two mating parts, measured radially.

Basic: The theoretical or nominal standard size from which all variations are made.

Crest Clearance: Defined on a screw form as the space between the crest of a thread and the root of its mating thread.

Allowance: An intentional difference in the dimensions of mating parts. It is the minimum clearance or the maximum interference which is intended between mating parts.

Tolerance: The amount of variation permitted in the size of a part.

Neutral Zone: A positive allowance. (See "Allowance.")

Limits: The extreme permissible dimensions of a part.

Multiple Thread: A screw thread that is formed of two or more single threads. For instance, a double thread is a multiple form having two separate or single threads starting diametrically opposite or at points 180 degrees apart; a triple thread has three single threads starting at points 120 degrees apart; and a quadruple thread has four single threads starting at points 90 degrees apart. A multiple thread is used to increase the lead of a screw without weakening it by cutting a coarse single thread.

Standard Screw Thread: A thread which conforms to an adopted standard in regard to the form or contour of the thread itself, and as to the pitch or number of threads per inch for a given screw diameter.

Special Screw Thread: A screw thread having either a modified form or a standard form but a pitch which is either greater or less for a given screw diameter than the adopted standard.

Scribner Rule. This is a rule employed for finding the board measure of logs, and is as follows: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply the result by the length of the log in feet; usually the diameter inside of the log at the small end is measured.

Scroll Chuck. This type of chuck, used in lathes and similar types of turning machines, is one in which the jaws for clamping the work move together and remain at the same distance from the center, the jaws being moved radially by a spiral scroll which engages teeth on the back of the jaws. When the scroll is rotated, the jaws are moved in or out by the action of the spiral engaging the teeth on the jaws. On most "scroll chucks," the rotation of the scroll is effected by turning a bevel pinion which meshes with bevel gear teeth cut on the back of the scroll. On some chucks, the scroll is turned either by direct hand or lever pressure. In one design of scroll chuck, the scroll is revolved by worm gearing, and another design is equipped with spur gearing, in which a spur pinion engages a spur gear cut on the edge of the scroll. Some scroll chucks are equipped with reversible jaws, the teeth on the jaws which engage the spiral scroll being formed so as to permit reversal.

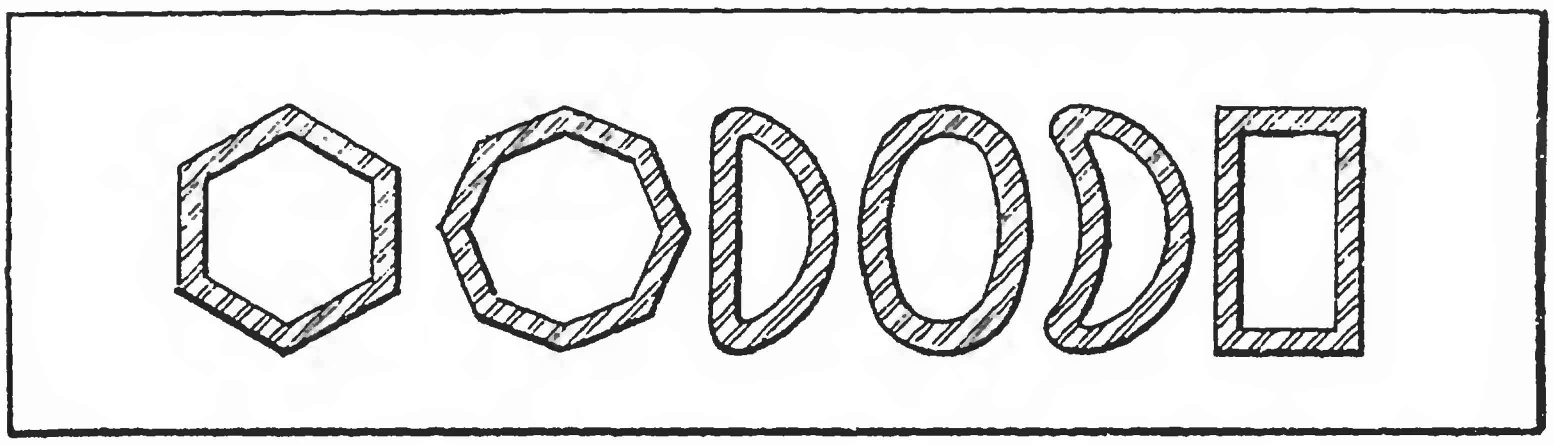
Scroll Lathe. The scroll lathe is a special type designed for cutting spirals or scrolls used for operating the jaws of scroll chucks, and for work of a similar nature.

Seale-Type Wire Rope. This rope is made from 6 strands of 19 wires each, and is also known as a "Seale hoisting rope." Sometimes this rope is made with a 6 by 12 construction, but this type is not recommended.

Seamless Brass and Copper Tubing. Seamless drawn brass and copper tubes are made in sizes varying from 1/4 to 8 or 10 inches in diameter. The sizes do not correspond with any universal standard, but usually increase by 1/8-inch increments up to 3 inches, and by 1/4-inch increments for larger diameters. The nominal diameter of tubes may be either the inside or outside diameter, brass and copper tubes being made to conform with both methods of measurement. The term "diameter," as applied to tubes, however, is generally understood to mean outside diam-

eter. The thickness of the tube walls conforms to Birmingham wire gage.

Seamless Steel Tubing. Seamless tubing of circular cross-section is made in a large range of sizes, and there are also a number of special shapes (see illustration). There are four different processes of producing seamless steel tubes for pipes: 1. By piercing a solid billet or forcing a punch through its center while in a red-hot state, and then rolling or hot-drawing the hollow billet thus formed, in order to reduce the wall thickness and elongate it to secure the necessary tube lengths. 2. By drawing from a circular flat plate a shallow cup, which is elongated by a successive series of hot-drawing operations over a solid mandrel and through a series of dies, thus reducing the wall thickness and increasing the length. 3. By using a hollow cast-steel billet of tubular form which is reduced and elongated by rolling over a mandrel, or by hot-drawing operations similar to those referred to. 4. By piercing a solid billet which, by means of angular rolls, is given a high rotative speed and a slow advancing movement

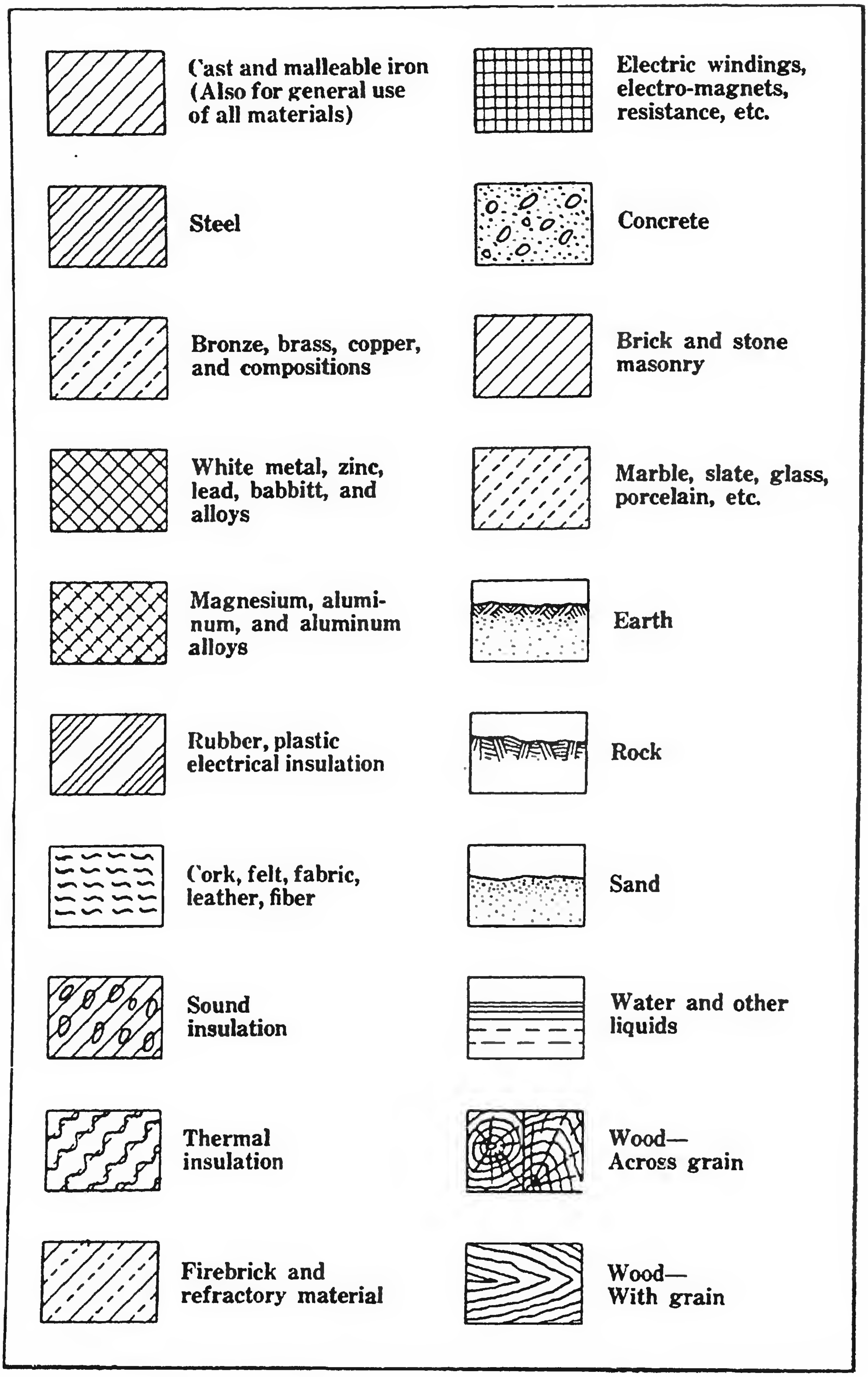


Some Special Shapes in which Seamless Tubes are Manufactured

over a pointed mandrel, thus changing the billet from a solid to a tubular form. The Birmingham wire gage is used for seamless steel tubing, to gage the wall thickness (see Mannesmann Process).

Season Cracks. In brass and other alloys, season cracks are defects due to molecular changes produced by mechanical deformation. These cracks become visible some time after rolling.

Seasoning Steel and Cast Iron. It is a well-known fact that hardened pieces of steel will undergo minute but measurable changes in form during a long period of time after the hardening has taken place. These changes are due to the internal stresses produced by the hardening process, which are slowly and gradually relieved. In order to eliminate slight inaccuracies which might result from these changes, steel used for gages and other tools requiring a high degree of accuracy is allowed to season before it is finally ground and lapped to the finished dimensions.



American Standard Section Lines used on Mechanical Drawings to Indicate General Classes of Structural Materials

The time allowed for this seasoning varies considerably among different toolmakers and also depends upon the form of the work and the degree of accuracy which is necessary in the finished product. Some toolmakers rough-grind the hardened part quite close to the finished size and then allow it to season or "age" for three or four months, and, in some cases, a year or more. Castings will often change their shape slightly after being planed, especially if the planed surface represents a large proportion of the total surface. To prevent errors from such changes, castings are sometimes allowed to season for several weeks or months, after taking the roughing cuts and before finishing. A common method of avoiding the long seasoning period is to anneal the castings. Artificial seasoning is also applied to steel parts by subjecting them repeatedly to alternate heating and cooling.

Secant of Angle. See Functions of Angles.

Sectional Dies. See Dies, Sectional Type.

Section Lines for Drawings. Various kinds of metals and other materials are used in machine construction and, when sectional views are made, it is convenient to have some standard method of cross-sectioning the different parts so as to indicate the kind of metal or material. The accompanying chart shows the lines and symbols which have been adopted as the American Standard.

Section Modulus. The section modulus of the cross-sectional area of a rod, bar, or beam is a value used in the calculation of the bending stresses in a beam subjected to load. The section modulus is equal to the moment of inertia of the cross-section, divided by the distance of the extreme fiber of the cross-section from the neutral axis. Generally the section modulus is denoted by Z; the moment of inertia, I; and the distance from the neutral axis to the extreme fiber, y. Then:

$$Z = \frac{I}{y}.$$

The polar section modulus, also known as the *section modulus of torsion,* equals, for circular sections, the polar moment of inertia divided by the distance from the center of gravity to the most remote fiber. This rule applies also with fair accuracy to sections that are nearly circular. For other cross-sections, the section modulus of torsion is not equal to the polar moment of inertia divided by the distance from the center of gravity to the most remote fiber. Methods have not yet been developed by means of which the section modulus of torsion may be calculated for cross-sections other than circular. Experiments have been made, however, and the section modulus of torsion has been determined in this manner for the most common cross-sections

Seger Temperature Cones. The fusible cone is a means for determining high temperatures in which the unequal fusibility of clay or earthenware blocks of varied composition is used. This means for determining temperatures is in use in pottery works and similar industries. The most well-known cones are known as the *Seger temperature cones*, also known as the *Sentinel temperature cones*. The Seger temperature cones are in the form of triangular pyramids (about 3 inches high), composed of metallic and mineral substances which fuse at certain temperatures. They are made in series, each successive cone having a fusing temperature that differs slightly from the one above or below in the scale; that is, if the series were placed in a furnace and the temperature gradually raised, one cone after another would melt as its melting point was reached. These cones are sometimes used in pairs to determine the minimum and maximum temperatures for a given process, one cone being selected for the lowest and another for the highest temperature required. Tests have shown that this method for determining temperatures is very trustworthy within 35 degrees F.

Segregation. Segregation is that natural phenomenon in the solidification of steel ingots in which various components of the steel having the lowest freezing points are concentrated in parts of the ingot last to solidify. This concentration at different locations results in such a distribution in the ingot that certain areas contain more, while others contain less, of a given element than the average composition of the ingot as a whole. In the case of some ingots segregation alone is not the sole cause of uneven distribution of desirable and undesirable elements, but in addition the chemical reactions between components of the steel which take place due to conditions developed in the cooling and solidification may be contributing causes.

Segregation varies in amount or degree, the chief determining factors being (1) rate of freezing of the metal, which is conditional upon the size and to some extent the form of the ingot; (2) composition of the steel; (3) type of steel desired: rimmed, semi-killed or killed. It is apparent that these factors which determine the amount of segregation are related to the size and kind of product ordered.

Seizing. The term seizing is used with reference to bearings to designate the condition when the shaft will not move freely, or at all, within the bearing, on account of lack of lubricant. In the absence of lubricant, the shaft and bearing are likely to scratch and score each other, and the increase in friction suddenly produces a high temperature which causes an expansion of the shaft and of the interior parts of the bearing, so that the

bearing box grips the shaft with an enormous pressure, or "seizes" the shaft.

Selective Assembly. Selective assembly consists of selecting by trial mating members of a mechanism that will give the desired fit at assembly, with little or no further machining or fitting. Companion parts made to the extreme limits are not supposed to interchange. For instance, a shaft or pin of maximum size may not assemble with a mating part of minimum size, although the maximum shaft and maximum hole and also the minimum shaft and hole must interchange. A good example of this selective method of assembling is found in the production of ball bearings. The balls are sorted into groups, according to their size, to facilitate the assembly of any bearing with balls of uniform size. Nearly every so-called "interchangeable" mechanism represents a combination of interchangeable and selective methods of quantity production.

Selenium. Selenium is a non-metallic chemical element. It possesses the peculiar quality or property of having its conductivity greatly increased by light. This property has been the basis of various electrical inventions, as for example, in various forms of apparatus for transmitting photographs by wire. Selenium has also been used in instruments for measuring the Roentgen rays used in therapeutic applications; in a form of Wheatstone bridge; in appliances intended to light and extinguish automatically the flame on gas buoys; in controlling street lights, electric signs, and moving pictures; in burglar alarms; and in controlling submarine boats. Selenium is used very largely in the making of glass, to which it gives a red color. It is also used to give a bright red color to enamels used on "enameled ware." The atomic weight of selenium is 79.2. Its specific gravity is 4.8, and it melts at a temperature of 217 degrees C. (423 degrees F.). Its specific heat varies from 0.072 to 0.115.

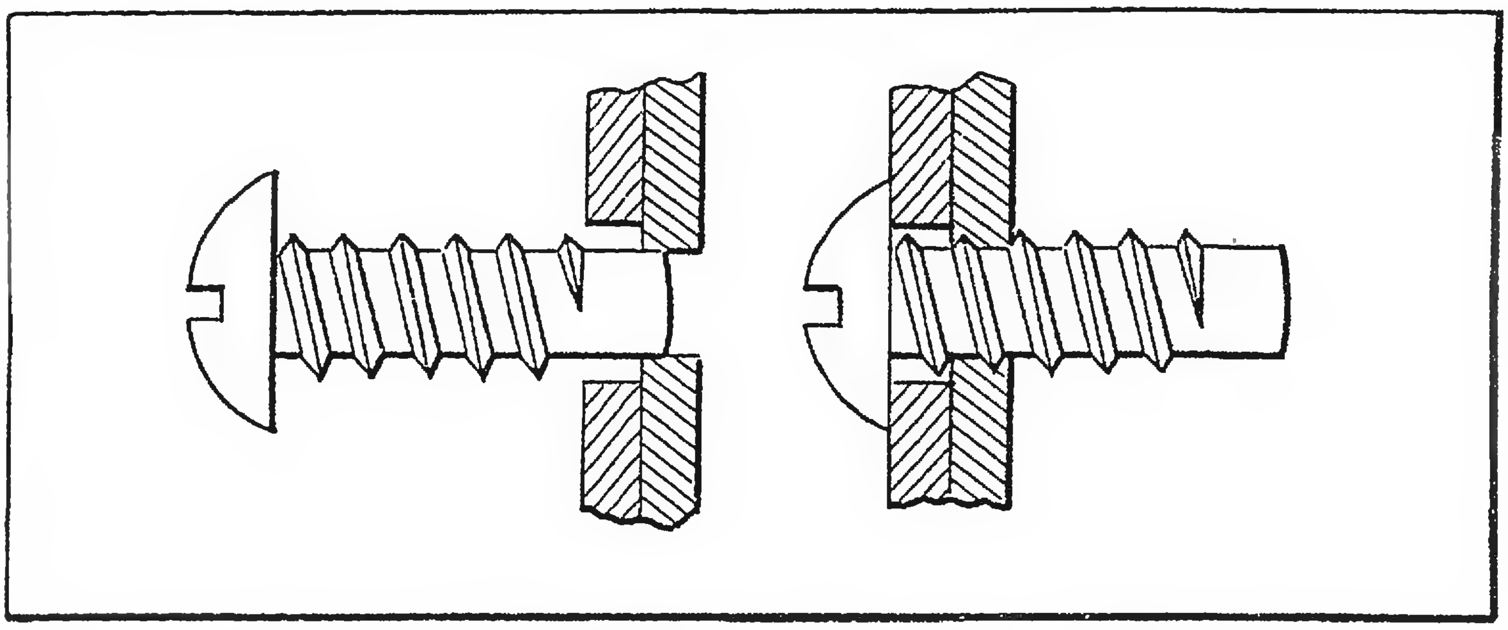
Self-Aligning. This term is applied to machine members that are so mounted that they can adjust themselves within certain limits. The self-aligning principle, for example, is employed in certain bearings which are so mounted that the bearing can adjust itself to the alignment of the shaft.

Self-Opening Dies. See Dies for Thread-cutting.

Self-Starter. In electric motor operation, a self-starter is an automatic starting device in which the starting box or controller is automatically operated or capable of being started by pushing a button or closing a switch at some remote point. Self-starters prevent the starting of motors too suddenly, and when combined

with float switches, pressure regulators, and limit switches, the motor may be started and stopped automatically at the proper time. These devices are most commonly used in connection with motor-driven pumps and air compressors.

Self-Tapping Screw. The self-tapping screw is designed to cut its own thread in die- or sand-cast parts of gray iron and softer metals. The screw has a V-thread of fairly coarse pitch and a cylindrical pilot which steadies the thread while it seats itself in the metal. See illustration. In using this screw, a hole is first drilled in the piece which would ordinarily be tapped, a few thousandths of an inch larger than the pilot, and the piece to be assembled is drilled sufficiently large to provide clearance for the threads of the screw. A common method of setting is to



Self-tapping Screw

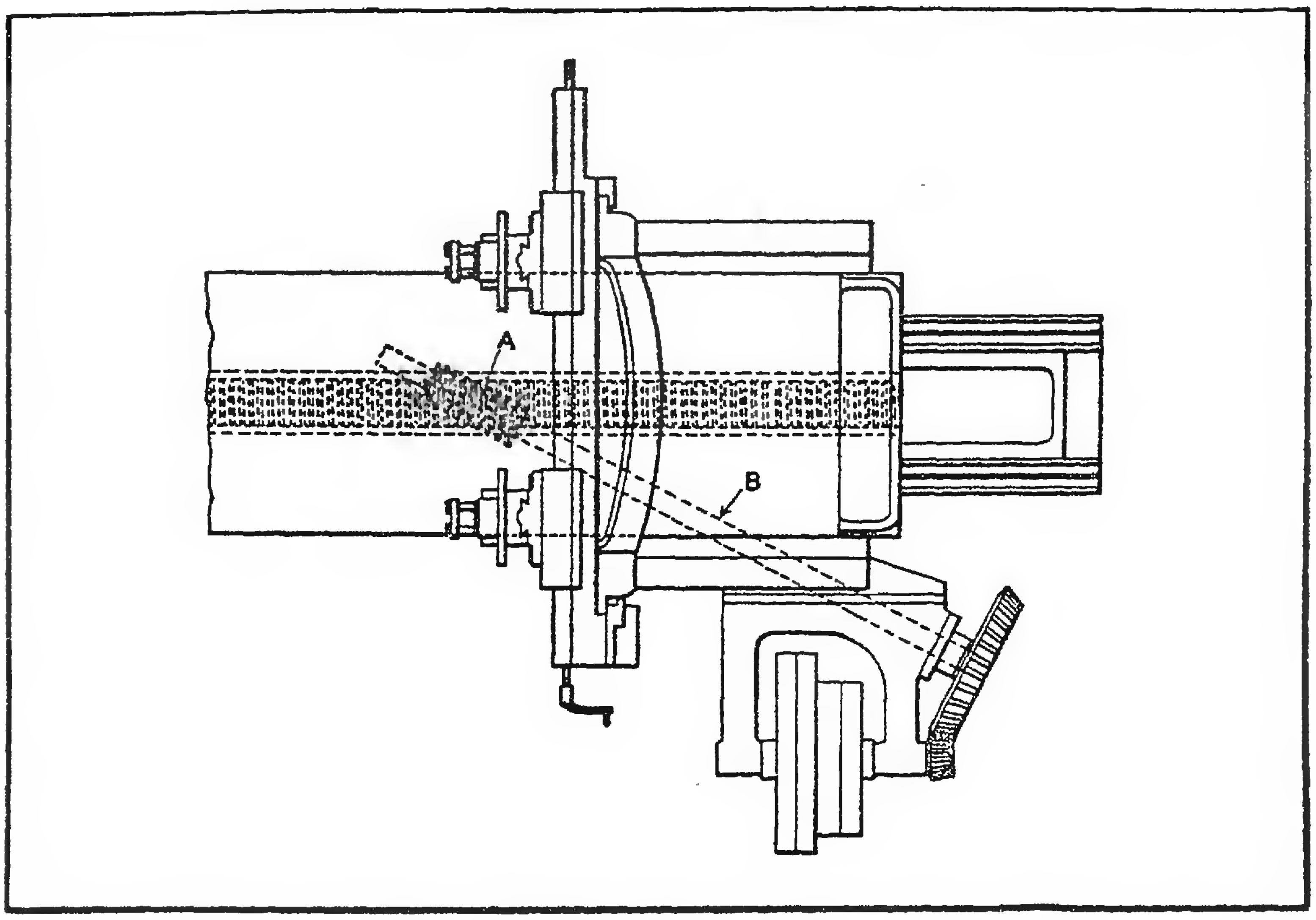
insert the pilot in the hole, make a few turns with a screwdriver, and then drive the screw into place. The entire screw is hardened and heat-treated so that the thread cuts into the metal.

Sellers Drive for Planers. There are two general methods of driving a planer table. The most common form of drive is that in which the motion is transmitted from the driving shaft through spur gearing to a "bull-wheel" or spur gear, which meshes with a rack attached to the under side of the planer table. A planer driven in this way is known as a "spur-geared" type to distinguish it from the "spiral-geared" planer. With a spiral-gear drive (also known as the *Sellers drive*) the motion is transmitted from the source of power through bevel gears to a shaft *B* which extends under the bed diagonally and carries a spiral pinion or worm *A*, which meshes with the table rack. See illustration.

Sellers Muff Coupling. This is a coupling consisting of two split sleeves, conical on the outside, forced together over the ends

of the shafts by bolts. An outside sleeve, tapered to fit the conical bushings, is provided for closing up the split cones when the nuts on the bolts are tightened.

Sellers Screw Thread. The Sellers screw thread, later known as the "United States standard thread," and now as the "American Standard," is the most commonly used screw thread in the United States. It was originated by William Sellers, of Philadelphia, and first proposed by him in a paper read before the Franklin



Plan of Sellers Planer Drive

Institute, in April, 1864. In 1868, it was adopted by the United States Navy and has since become the generally accepted standard screw thread in the United States.

Selsyns. Selsyns, also called *autosyns* and *synchroties,* are self-synchronous electrical machines used to synchronize the rotation of two shafts that have no mechanical connection. Selsyns are used in power applications, control systems and instruments.

Semi-Anthracite Coal. This is a kind of coal similar to, but not as hard as, regular anthracite, being less shiny and burning more rapidly. It contains from 85 to 90 per cent of carbon. The heating value varies from 14,500 to 15,500 B.T.U. per pound of combustible.

Semi-Automatic Machine. This term is generally understood to describe a machine which performs a complete cycle of operations automatically, but which requires the attention of an operator each time a part is finished. Many machine tools which actually are semi-automatic are classed as "automatic" by their manufacturers.

Semi-Bituminous Coal. This coal is softer than anthracite and has a tendency to produce more smoke. It contains from 75 to 85 per cent of carbon and has a heating value of from 15,500 to 16,000 B.T.U. per pound of combustible. It is one of the best coals for power plant purposes.

Semiconductors. These materials, two of which are germanium and silicon crystals, are partly conductors and partly insulators. They are used to rectify, amplify, oscillate or limit a current. In the case of germanium, the upper operating temperature limit is 80 degrees C., whereas with silicon it is 300 degrees C. Other semiconductor materials are selenium, copper oxide and titanium oxide.

Semi-High-Speed Steel. The so-called semi-high-speed or intermediate steel was produced to meet the demand for a steel which could be used just as well as high-speed steel for certain purposes, and still be much lower in price. The quality of this steel, as far as cutting speed is concerned, is somewhere between ordinary carbon steel and the modern high-speed steel. It contains a much smaller percentage of tungsten than regular high-speed steels, and is sometimes called a low-tungsten steel.

Semi-Steel. Semi-steel is made by adding mild steel to the pig iron and scrap in the cupola. The proportion of steel used varies from 15 per cent for light castings to 40 per cent for heavy castings. The resulting metal is a high-grade cast iron with fewer impurities and better physical structure than ordinary cast iron, and while this metal has practically no elongation or ductility, it is stronger than gray cast iron under transverse, tensile, compression, and impact tests, and is superior in elasticity, toughness, and resistance to shock and wear. When properly made, it is close-grained, homogeneous, and free from hard spots and blow-holes. It is greatly superior to gray iron for machinery, and takes on a finer polish, and permits the cutting of clean screw threads. It is especially good for such castings as cylinders, pistons, and gears, and other parts which are subjected to wear and friction. The 20 per cent mixture usually gives the desired results for machine tool work.

Semi-Vitrified Grinding Wheels. The term "semi-vitrified" is sometimes applied to grinding wheels made by the silicate bonding process. See Silicate Bonding Process.

Sensitive Drilling Machine. See Drilling Machines.

Sentinel Pyrometers. These consist of different metallic salts which are made up in mixtures that will melt at various specified temperatures ranging from 220 to 1330 degrees C. (428 to 2426 degrees F.). This method of measuring temperatures is intended to replace more costly pyrometers and also for the purpose of checking the indications of pyrometers. See also Seger Temperature Cones.

Separators, Chip, Oil, and Work. See Chip and Oil Separators; also Chip and Work Separators.

Separators, Steam. See Steam Separators.

Septivalent. This term is used to indicate that an atom of one element will combine with seven atoms of another element.

Series Connection. In any electrical circuit, two or more elements such as resistances, inductances, condensers, lamps, motors, etc., are said to be connected in series when they are so joined that an electric current in flowing around the circuit must pass through each one successively.

Electric batteries are connected in series when the positive or plus (+) terminal of one cell is connected to the negative or minus (—) terminal of the next cell. This connection increases the internal resistance, making it equal to the resistance of one cell multiplied by the number of cells. The electromotive force of the whole battery also equals that of one cell multiplied by the number of cells, but the amount of current of the whole battery remains the same as that of a single cell. See also Parallel Connection.

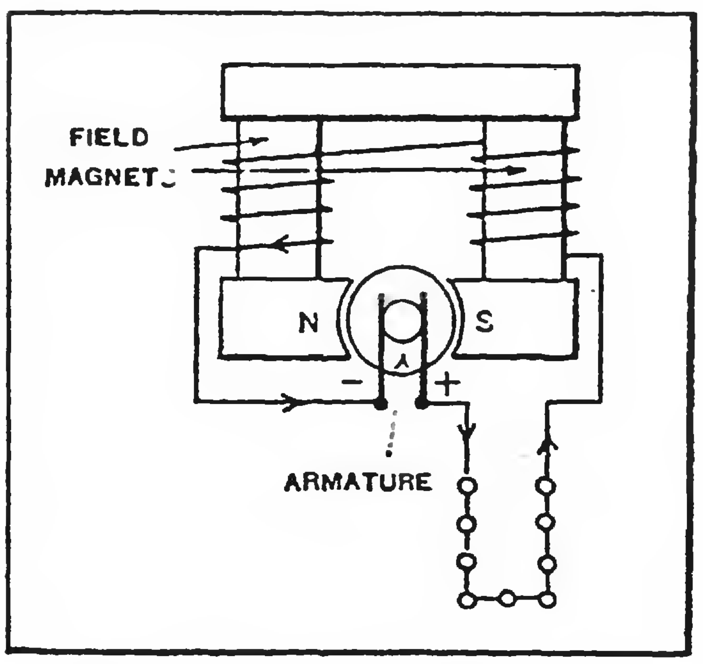


Diagram of Series-wound Generator

Series-Wound Generator. This is a direct-current generator in which the field winding connected in series with its armature winding and the external circuit, as shown by the diagram. The whole current delivered by the machine flows through the field winding and the voltage varies with the load, increasing as the load increases, and vice versa. The usefulness of a series generator is, therefore, confined mainly to such services as require a fairly constant current, such as series arc-lamp circuits.

The field winding is composed of heavy wire or strap in order to carry the large current without undue heating.

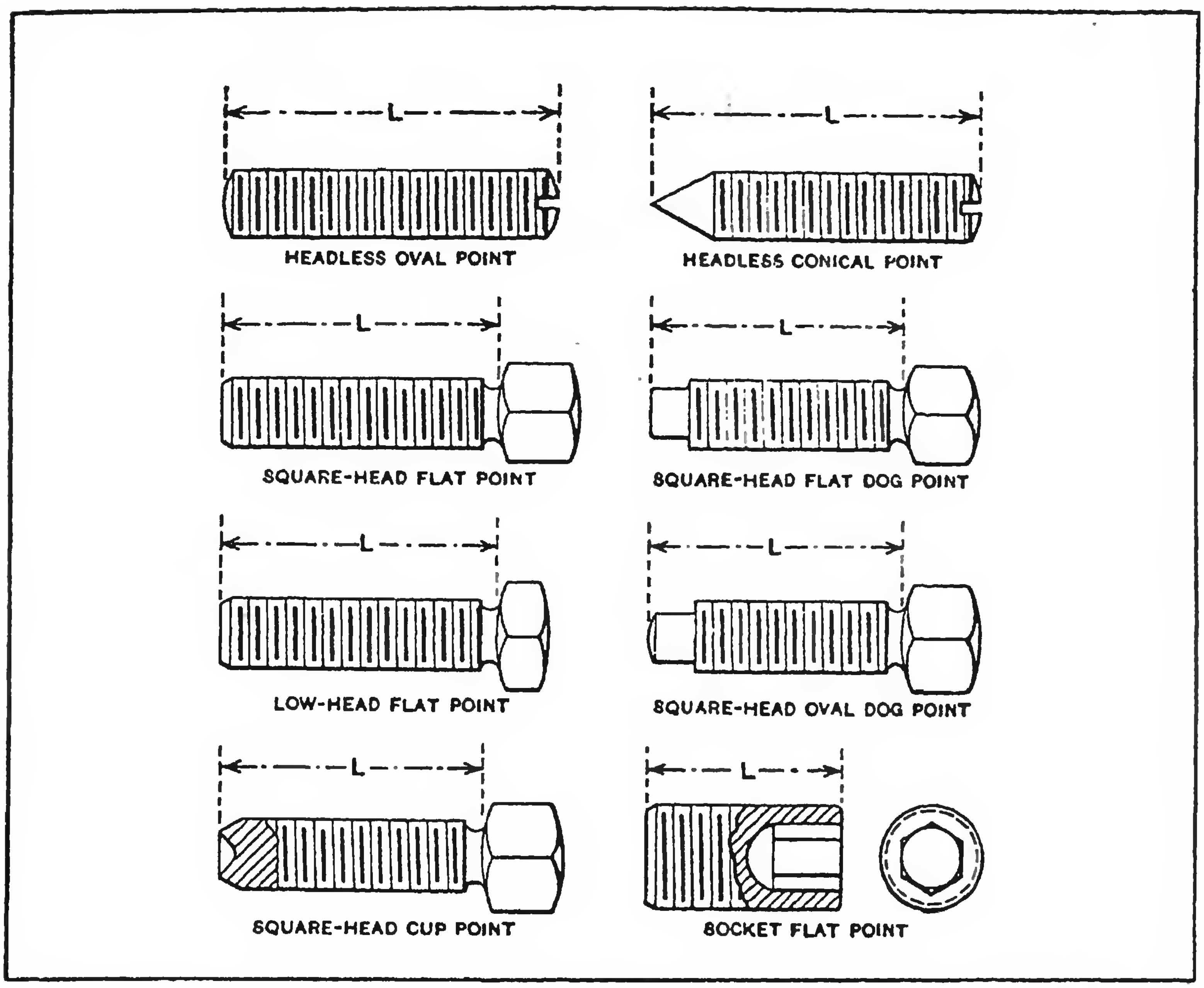
Series-Wound Motor. The three types of direct-current motors are series-wound, shunt-wound, and compound-wound motors. The series-wound motor is one in which the field winding is in series with, or forms a direct continuation of, the armature circuit, so that all of the current that passes through the armature passes also through the fields. The amount of current drawn from the line by a motor depends upon the work, or horsepower, which the motor is developing. It therefore follows that in the series motor the strength of the fields will depend upon the load which is placed on the motor, and, as the speed of the motor depends inversely upon the field strength, the speed of the series motor will be inversely proportional to the load. Since the speed of a motor also depends upon the voltage that is impressed upon the armature, the speed of a series motor may be controlled by introducing resistance in series with the armature, and this is accomplished by means of a controller which is used also for starting the motor. The use of the controller enables the operator to start the motor slowly under light loads, and also prevents too great a flow of current when starting under heavy loads. The characteristics of the series motor are heavy starting torque and a speed dependent upon the load.

Serrations. See Splines and Serrations.

Servomechanism. A servomechanism is any device in a closed-loop feedback system which can control the input power after having measured conditions at the output end of the system to correct for any deviation from the desired output. The input power is usually of a low energy level and that of the output a high energy level or power.

Servomechanisms may be electronic, pneumatic, hydraulic, etc. but most common are the electrical and electronic devices because of their preciseness and sensitivity. They are installed to automate such industrial processes as the forming and cutting of metals and the reduction and processing of ores.

Set-Screws. The principal difference between a set-screw and a cap-screw is that the former bears on its point, whereas a cap-screw bears on its head. Set-screws are generally used to prevent relative motion between two machine parts, as, for example, when a set-screw passes through a tapped hole in the hub of a pulley and bears against a shaft which drives the pulley. Keys are preferable to set-screws for locking pulleys, gears, etc., to their shafts, and for similar work, although set-screws may serve the purpose when not subjected to heavy loads; they are used principally on the cheaper grades of machinery. Set-screws are



Set-screws

not only used for locking parts together, but also as a means of obtaining slight adjustments, either to eliminate unnecessary play by means of gibs, or for changing the location of a tool or other part. The illustration shows some common forms. On account of the danger caused by the projecting head of set-screws, hollow or "safety" set-screws are now used extensively. These have either a hexagon socket or a fluted socket in the end for a wrench, instead of a projecting head.

Sexivalent. This is a term used to indicate that an atom of one element will combine with six atoms of another element. It is also known as hexavalent.

Shaft Couplings. See Couplings for Shafts; also Flexible Couplings.

Shafting. Shafting is used for transmitting power from one point to another and for supporting the means employed in power transmission, such as gears, pulleys, chain wheels, clutches, etc. The stresses to which shafts are subjected may be chiefly *torsional* stresses, chiefly *bending* stresses, or *combined torsional and bending* stresses. Shafts which simply transmit power from one

point to another will, if supported by a sufficient number of bearings, be subjected chiefly to torsional stresses. Shafting of this type is found in the line-shafting in shops and factories. If, however, heavy pulleys and gears are supported by the shaft and especially if they are not located close to the bearings, the shaft may be subjected to severe bending stresses in addition to the torsional stresses due to the transmission of power. The axles of large water wheels are subjected chiefly to bending stresses and, for a short section only, to torsional stresses.

Shafting, Cold-Drawn. See Cold-drawing.

Shafting Diameters. The diameter of shafting for transmitting a given amount of power may be determined by the following formulas which are taken from the American Standards Association's Code for the Design of Transmission Shafting. In these formulas:

D = outside diameter of shaft in inches;

K_m = combined shock and fatigue factor to be applied in every case to the computed bending moment (for rotating shafts, $K_m = 1.5$ for gradually applied or steady loads; 1.5 to 2 for suddenly applied loads and minor shocks only; 2 to 3 for suddenly applied loads and heavy shocks);

K_t = combined shock and fatigue factor to be applied in every case to the computed torsional moment (for rotating shafts and gradually applied or steady loads $K_t = 1$; for suddenly applied loads and minor shocks only K_t = 1 to 1.5; for suddenly applied loads and heavy shocks K_t = 1.5 to 3);

M = maximum bending moment in inch pounds;

N = revolutions per minute;

P = maximum number of horsepower to be transmitted by the shaft;

p = maximum shearing stress in pounds per square inch (the maximum shearing stress p, under combined load = 8000 pounds per square inch for "commercial steel" shafting without allowance for keyways, and 6000 pounds per square inch with allowance for keyways. p = 30 per cent of the elastic limit in tension, but not more than 18 per cent of the ultimate tensile strength for shafting steel purchased under definite physical specifications);

S_s = maximum permissible torsional shearing stress in pounds per square inch (the values for S_s are the same as just given for p);

T = maximum torsional moment in inch pounds.

If a solid circular shaft is subjected to a pure torsional load

$$D = \sqrt[3]{\frac{321{,}000\, K_t P}{S_s N}}$$

If a solid circular shaft is subjected to combined torsion and bending

$$D = \sqrt[3]{\frac{16}{\pi p}\sqrt{(K_m M)^2 + \left(\frac{396{,}000\,K_t P}{2\pi N}\right)^2}}$$

Distance between Bearings: The bearings for shafting should be located close enough to limit the maximum deflection of the shaft to about 0.010 inch per foot of length. For average conditions the maximum distance between shaft bearings in feet may be determined by the following rules: For bare shafts, extract the cube root of the *square* of the shaft diameter in inches, and multiply this root by 6.3. For shafts carrying pulleys, etc., the cube root of the square of the shaft diameter in inches is multiplied by 5.2.

Shafting Diameters, Standard. American Standard diameters for finished shafting include "transmission shafting" and "machinery shafting." There are eighteen standard sizes for transmission shafting ranging from 15/16 inch up to 8 inches. There are forty standard sizes of machinery shafting ranging from 1/2 inch up to 8 inches. The stock lengths of finished transmission shafting are 16, 20, and 24 feet.

Shafting, Flexible. See Flexible Shafting.

Shaftless Motor. A shaftless motor is usually designed to be an integral part of some machine. It differs from the usual type of motor in that it has no shaft of its own, but has its rotor mounted directly on the shaft of the machine to be driven. This obviates need for any form of transmission between motor and machine. This type of motor is used in machine tools and woodworking machines where extreme compactness is desired.

Shale Oil. See Oil Shale.

Shaper Classification. The shaper, like the planer, is used principally for producing flat or plane surfaces, but it is intended for smaller work than is ordinarily done on a planer. The shaper is preferable to the planer for work within its capacity, because it is less cumbersome to handle and quicker in its movement. Shapers are classified in several different ways. For instance, the name applied to a given design may indicate the action of the machine when in operation, the type of driving mechanism, or other constructional features. The *crank shaper* is a very common design, and the name relates to the crank-driving mechanism for the ram. There are also *geared* or *rack shapers*, which are so named because the ram is driven through gearing and a rack attached to the ram. The crank-driven type is the one that

is used principally. The details of different makes of the same type vary to some extent, but all shapers of the same class have certain essential features that are quite similar.

Friction Shaper: The name "friction shaper" is sometimes applied to a geared shaper which is equipped with friction clutches for reversing the movement of the ram, instead of using shifting belts. There are two pulleys rotating in opposite directions, and these are alternately engaged by friction clutches which are operated by the tappets or dogs attached to the ram. These shapers avoid the shifting of the driving belts, and operate on the same principle as clutch-driven planers.

Traveling-head Shapers: The traveling-head or traverse shaper differs radically from the standard type. The machine is equipped with a rather long box-shaped bed upon which the ram is mounted. This ram is carried by a saddle which feeds along the top of the bed when the shaper is in operation. The feeding movement of the saddle is at right angles to the traversing motion of the ram. Some shapers of this type are equipped with two shaper heads instead of one. A machine of the duplex type is very efficient for planing certain classes of work, especially if the parts are quite heavy or unwieldy, because the work remains stationary and it may be supported either by the adjustable tables or be placed upon the floor. Obviously the double-head machines may be used for planing separate parts, or, at times, the two heads may be used for planing each end of a long casting at one setting of the work.

Open-side Shaper: A Richards or open-side shaper has a saddle which is traversed along the top of the bed by a screw, and the tool-slide is mounted upon a cross-rail located at right angles to the bed. When the shaper is in motion, the saddle and its attached head traverses to and fro along the bed, and the tool-slide is fed laterally, either by hand or automatically. The open-side shaper is superior to either the column or traverse shaper for many classes of work, especially when long and comparatively narrow surfaces need to be planed.

Draw-cut Shaper: A shaper of the draw-cut type differs from the ordinary design in that the tool cuts when it is moving toward the column of the machine. In other words, the tool is pulled or drawn through the metal on the cutting stroke instead of being pushed. For this reason, the name "draw-cut" is applied to a shaper of this type. The planing tool is set with the cutting edge reversed. The object in designing a shaper to take a draw cut is to secure greater rigidity and, consequently, a higher degree of accuracy. The thrust of the cut is toward the column and this tends to relieve the cross-rail and other bearings from excessive strains, especially when taking deep cuts. As the

ram is subjected to a tensile stress, it is claimed that vibrations are practically eliminated and that the tendency to vibrate diminishes as the depth of cut increases.

Vertical Shaper: This machine resembles a slotter in many respects, but it is known as a vertical shaper and is adapted for classes of work that are done on horizontal shapers and regular slotting machines. The work-table of this shaper can be given a transverse, longitudinal, or rotary movement. The ram which carries the planing or slotting tool moves vertically, while the table is fed either by hand or automatically in whatever direction is required. The ram can be placed perpendicular to the table or at an angle for slotting dies, etc. It is mounted in an independent bearing, the upper part of which is pivoted, so that both the bearing and ram can be adjusted to an angular position, which is indicated by degree graduations. Work can often be completed at one setting by a shaper of this type, as it may be used for machining either straight, curved, or irregular surfaces.

Shaper, Gear. See Gear Shaper.

Shaper Invention. The shaper for planing metals, was invented by James Nasmyth who was one of Maudslay's pupils. Maudslay perceived that Nasmyth was an extraordinarily skillful workman, and he not only employed him, but took him into his own office as his personal assistant. Nasmyth stayed for several years or until Maudslay's death, in 1831, when he started in business for himself. He became one of the foremost tool builders in England, and invented the shaper in 1836 which was long known as Nasmyth's "steel arm." The "quick return" was first applied to the shaper by Whitworth.

Sharp Sand. Sharp sand is lake or seashore sand, river sand, bank sand, or silica or fire sand, used in the making of cores for the foundry. The sand is mixed in varying proportions with fine grades of molding sand.

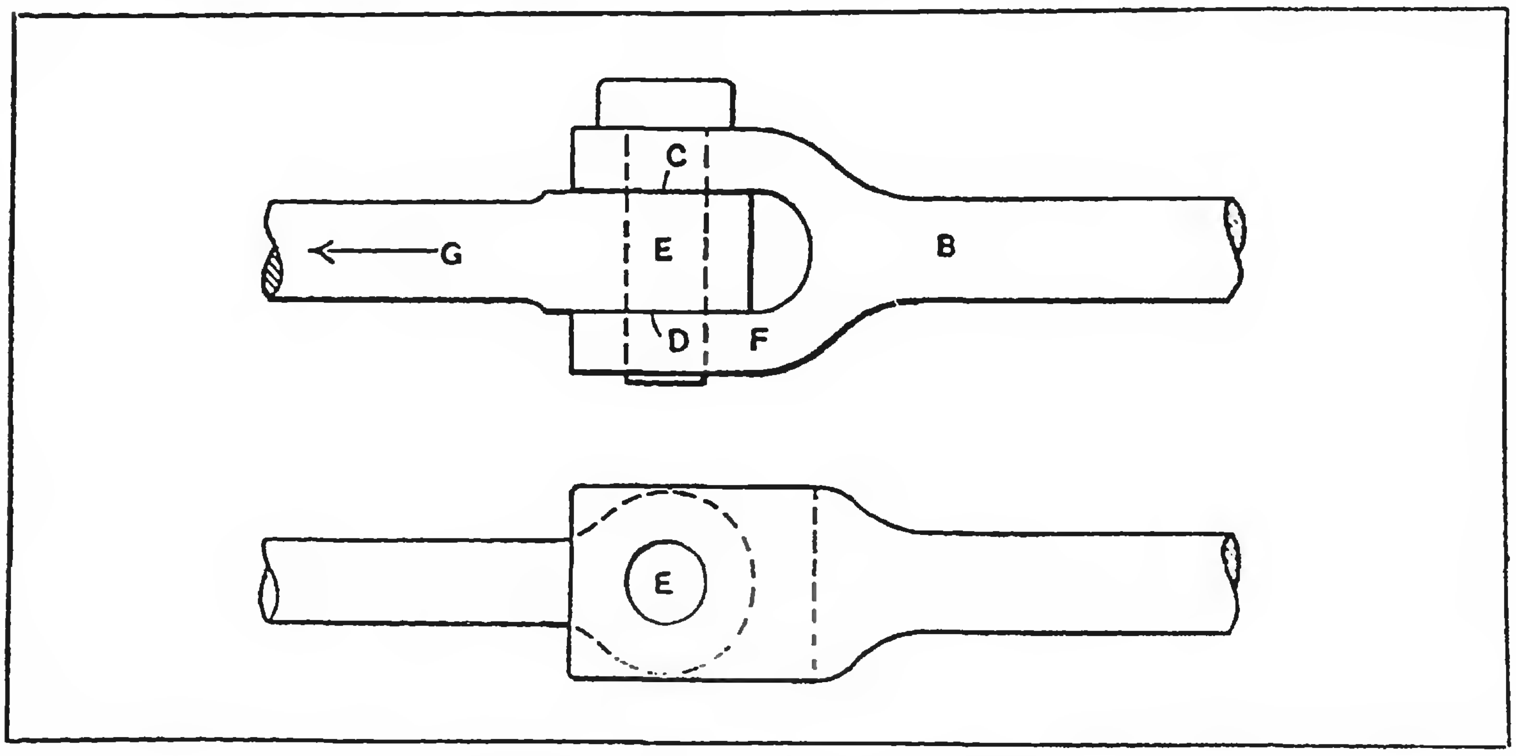
Shaving Dies. Dies of this class are sometimes used for finishing the edges of comparatively thick blanks which have been cut out in a regular blanking die. A blanking die used for cutting heavy stock must have a certain amount of clearance between the punch and die opening, the amount depending upon the thickness and kind of material. As the result of this clearance (which lessens the danger of breaking the punch and reduces the pressure required for the punching operation), the edges of thick blanks are somewhat rough and also tapering. To secure smooth, square edges, *shaving dies* are used in some cases.

Shaving Gear Teeth. The shaving process is employed for finishing the teeth of precision gears. The gear to be finished is rolled relative either to a rack-shaped or rotary form of cutter,

while the gear and the finishing tool are moved laterally relative to each other. This shaving process is used extensively in the automotive industry and also for such precision work as finishing turbine or other reduction gear units. Shaving is a cutting rather than cold-working process, although a very small amount of metal is removed in correcting the tooth profile. This process is applied to unhardened gears, the hardness of material usually varying from 25 to 30 Rockwell C scale. In the aircraft industry, it is a general practice at the present time to finish gear teeth by grinding after hardening. While the distortion resulting from hardening might be controlled to a certain extent by the design of the gear and the material used, it cannot be fully eliminated; hence, the present practice is to grind aircraft gears notwithstanding the cost of this process as compared with the shaving method of finishing. See Gear-Finishing Machines; also Gear-Tooth Grinding.

Shaving Tools. When forming work of irregular contour, in the automatic screw machine it is common practice to use a shaving tool which is operated tangentially to the work and passes either under it or over it as conditions may require. It is customary to place the shaving tool on the rear cross-slide, so that the shaving operation can be accomplished at the same time as the turret operations, when the spindle is running forward. The chief use of this tool is for finishing work after it has been rough-formed with a circular form or other external cutting tool.

Shearing Machines. The shears or shearing machines used in boiler shops, shipyards, machine shops, etc., for splitting or trimming steel plates and for cutting off bars and structural material, are made both in hand- and power-operated types, and in many different designs. The machines used for shearing are,



Pin Subjected to Shearing Stresses

in many cases, also adapted to punching operations by replacing the shear blades with one or more punches and dies. There are also combination designs having a punch on one side and a shear on the other. A shearing machine of the ordinary type is equipped with one fixed blade and one movable blade which receives motion from a mechanism designed to give a powerful cutting movement. The blades intended for different classes of work vary in form and the motion of the blade relative to the material being sheared also varies on different types of machines. One of the simplest and oldest types of power-driven shearing machines is known either as a *lever shear*, an *alligator shear*, or a *crocodile shear*. It is adapted to the shearing of scrap, or for cutting billets, muck bars, and sheet bars in rolling mills, and for similar work. Another design of shearing machine is known as a *vertical* type. The upper or movable shear, instead of being attached to a pivoted lever, is bolted to a slide which is given a vertical reciprocating motion. The vertical design is often preferred to the horizontal machine where economy of floor space is important. Some shears have a vertical reciprocating slide which is operated by a lever connected by a pitman with a crankshaft at the rear.

Shearing Stresses. The pin E (see diagram) is subjected to a shearing stress. Parts G and B are held together by the pin and tend to shear it off at C and D. The areas resisting the shearing action are equal to the cross-sectional areas of the pin at these points. The general formula for shear is: Load = cross-sectional area $\times$ working stress. The permissible working stress for shear is assumed as four-fifths or five-sixths of the permissible working stress in tension. If a pin is subjected to shear so that two surfaces, as at C and D, must fail by shearing before breakage takes place, the areas of both surfaces must be taken into consideration when calculating the strength. The pin is then said to be in *double shear*. If the lower part F of connecting-rod B were removed, so that member G were connected with B by a pin subjected to shear at C only, the pin would be said to be in *single shear*.

Shear of Punches and Dies. When the cutting face of a die is inclined each way from the center, or is made hollow, it is said to have *shear*. The cutting faces of dies are given shear for the same reason that the teeth of some milling cutters are made helical or spiral, in that the shear makes it possible to cut the blank from the sheet with less expenditure of power and, therefore, reduces the strain on the punch and die. Whether a die should be given shear or not depends upon the thickness of the stock to be cut and, in some cases, upon the power of the press

available. When shear is required it is advisable sometimes to leave the face of the die flat and give shear to the punch instead. In general, the shear is given to the punch when the stock around the hole is the desired product and the material removed by the punch is the scrap. The face of the die is sheared when the blank or that part which is cut out by the punch is the product.

Shears, Squaring. See Squaring Shears.

Shear Steel. This steel is usually in the form of bars, and is made from blister steel, by shearing it into short lengths, arranging in piles, and welding these piles by rolling or hammering at a welding heat. If this process of shearing, etc., is repeated, the product is called "double-shear steel." Shear steel is made principally in England and is used for articles of cutlery, etc.

Shear Theory, Maximum. See under Stress Theories.

Sheet. A finished rolling mill product known as a "sheet" is produced by rolling sheet bars in sheet mills. The term "sheet" is applied to material having a thickness less than No. 12 gage. (The United States Government limits the thickness of sheets to No. 10 U. S. Standard gage.) Ordinarily, sheet mills do not roll stock thinner than No. 30 gage.

Sheet Bar. A "sheet bar" is a semi-finished rolling mill product that is flat and less than 2 inches thick, and from 6 to 12 inches wide.

Sheet Iron. Sheet iron may be either black or galvanized. Galvanized sheets should be thoroughly and evenly coated, of bright appearance, and free from blisters, ragged edges, or other defects. The zinc coating should not flake or peel off when scraped with a knife, or when the sheet is bent sharply to right angles. The sheet should never be re-rolled after leaving the galvanizing bath, except for the purpose of straightening. The zinc used for galvanizing should contain at least 98 per cent pure zinc. The minimum zinc coating per square foot for galvanized plates should vary from 1.35 to 1.65 ounce, the smaller value being used for the thinnest sheets and the higher value for the heavier sheets.

Sheet Metal Gages. Sheet metal gages or gaging systems vary for different classes of materials, such as ferrous and nonferrous metals. Gage numbers and equivalent thicknesses are given in engineering handbooks. See Sheet Steel; also Gages for Sheet Metals.

Sheet-Metal Testing. Tensile strength tests are unsatisfactory for determining the quality of thin sheet metal that is to be worked in power presses, etc., because of two reasons: in the first place, such tests do not yield reliable data for very thin

sheets; second, the quality of metal which is to be worked by drawing, stamping, folding, etc., is dependent upon ductility and similar properties rather than upon tensile strength. A machine has been developed for determining what is known as the Erichsen value, i.e., the depth in millimeters before the metal is torn, of an impression made by forcing the sheet metal through a die. See Erichsen Value.

Sheet Steel. Sheet steel is made from soft steel containing a low percentage of carbon. The Manufacturers' Standard plate gage sizes most generally considered under the heading of "sheet steel" are those from No. 10 (0.1345 inch thick) down to No. 30 (0.012 inch thick). Sheets corresponding to the various gage numbers between these limits are made in widths of 24, 26, 28, and 30 inches, and in lengths of 72, 84, 96, and 120 inches. Nos. 10 to 16, inclusive, are also made in widths of 36, 40, 42, and 48 inches, and in lengths of 144 inches, and Nos. 17 to 24, inclusive, are also made in sizes 36 inches in width and 144 inches long. See Cold-rolled Sheet Steel.

Shellac, Pattern. See Pattern Varnish or Shellac.

Shelling. Shelling is the rupturing of the surface or shell surrounding the inner core of bar stock, which sometimes occurs when cold-drawing large sizes.

Shell Molding. In this technique, which does away with most of the disadvantages of sand casting, the pattern is usually made of metal and must be heated before being used. A mixture of fine sand and thermosetting phenolic resin (plastic) is poured over the pattern, and a thin shell of the mixture sticks to the hot pattern surface and hardens. After a short baking period, the shell is stripped off the pattern and is ready for use. In usual practice, the pattern is made in two pieces, an upper part, the "cope" and a lower part, the "drag."

The cope and drag shells are fastened together and packed in a box or "flask" with sand, springs, or fine steel shot to hold them in place and prevent them from breaking from the weight of the molten metal poured into them. The shell cannot be used again, but castings produced by this method have a fine surface finish and can be made accurate to within three one-thousandths of an inch, so, very little, if any, machining is required. The process is particularly useful for making castings with thin walls, because of the absence of defects, but it is still rather expensive on account of the high cost of the resins and the molding equipment.

Shell Reamers. Shell reamers have a hole through the center by means of which they are mounted on arbors, or detachable shanks. By making the reamers in this manner, one arbor

can be used for a number of sizes. The negative front rake on shell reamers should not be more than about 3 degrees. The corners at the end of the fluted shell reamer are slightly rounded.

Sherardizing Process. The sherardizing process was originated in England by Sherard Cowper-Coles about 1904. The process is applicable not only in all cases where hot or cold galvanizing can be used, but in numberless other cases where they cannot. Briefly, the process consists in packing the articles to be covered with the zinc coating into a closed drum, box, or other suitable receptacle in contact with the ordinary zinc dust of commerce. The receptacle is then put into an oven and gradually heated to the required temperature of about from 500 to 700 degrees F., for a period of four or five hours. At the same time, the retorts are turned intermittently so as to give the zinc dust access to all parts of the work. After holding this heat for several hours, the exact time depending upon the thickness of the coating desired, the drums are withdrawn from the furnace and allowed to cool down to a temperature convenient for handling, when its contents are dumped upon a screen, which allows the zinc dust to fall freely into the chamber below, from which it can be drawn for use again. The articles are found to be evenly coated with pure zinc. A sherardized surface is light gray in color, and the finish imparted is a fine matted surface resembling that obtained by sand-blasting.

The preparation of the surfaces of articles to be sherardized is important, if good results are to be assured. The presence of rust or scale greatly interferes with the sherardizing action. To prevent the articles from rusting after cleaning with acid by pickling they should be thoroughly neutralized by placing them in a boiling solution of cyanide, allowing 5 to 6 pounds of cyanide crystals to 100 gallons of water. If the articles are cleaned by sand-blasting there is no danger of rust. If sand-blasting cannot be done for some reason then correct pickling and after treatment are necessary before placing the articles in the sherardizing drum. A good pickling bath for cleaning iron or steel castings consists of 10 per cent each of hydrofluoric and sulphuric acid with 80 per cent water. The acids should be separately diluted before being added to the bath. A diluted sulphuric acid bath is sometimes used as a pickling solution for iron castings. After pickling with hydrofluoric or sulphuric acid, the castings should be washed in water, followed by an immersion in an alkaline (soda) solution to neutralize any remaining traces of acid. After being thoroughly cleaned the castings should be immediately transferred to a tank of clean water so as to preserve them from oxidation. When the sherardizing equipment is ready the cleansed castings may be put into the drums wet, as they come directly from the water tank.

Shim. In mechanical work a shim is a thin sheet of material (usually brass, steel or some other metal) which is sometimes applied between parts to provide convenient means of making adjustment either to compensate for wear or for other reasons. When a bearing, for example, is in the form of two half sections, a shim may be placed between these sections to provide later for adjustment either by inserting a thinner shim or by reducing the thickness of the one originally used. By thus reducing the thickness, the bearing sections are located closer together and play due to wear may be eliminated. The laminated shim is an improved form consisting of layers of metal which can be peeled off to obtain the desired thickness. This laminated form provides a quick and accurate method of obtaining adjustments by the shim method.

Shipping Measure. For measuring entire internal capacity of a vessel: 1 register ton = 100 cubic feet. For measurement of cargo approximately 40 cubic feet of merchandise is considered a shipping ton, unless that bulk would weigh more than 2000 pounds, in which case the freight charge may be based upon weight. 40 cubic feet = 32.143 U. S. bushels = 31.16 Imperial bushels.

Shock. In mechanics, shock is the sudden application of a load to a structural or machine member. Machine parts subjected to shock must be stronger in proportion to the load which they carry than machine parts which are subjected to a steady load or to a load which gradually increases or diminishes.

Shock Resistance. Shock resistance is the ability of a metal to resist impact loads. It is usually measured in foot-pounds of energy required to fracture a notched bar, as determined by the Izod or Charpy tests on pendulum-type machines. However, many factors govern impact values, and any such value is meaningless if the nature of the test and the metallurgical condition of the sample are not specified.

Shore Scleroscope. See Scleroscope.

Short Circuit. A short circuit is an electrical connection of low resistance which diverts the flow of current from the device or equipment through which it would normally pass, along a shorter path. Such a connection may be established deliberately to cut out a certain piece of equipment or an element such as a coil, resistance, or condenser from the circuit, or it may be established accidentally as in the breakdown of defective insulation.

Short-Lap Belt. A short-lap belt is a leather belt made entirely from that part of the hide which comes from the back of the animal and in which the strips are not long enough to include any portion of the neck stock. This is the best kind of belting.

Short-Lead Attachment. In cutting screw threads or helical grooves of long lead in an engine lathe, it is well known that the gearing is subjected to severe stresses because of the high ratio of gearing required to traverse the carriage a distance per revolution of the spindle, equal to the lead of the groove being cut. The same difficulty is encountered in milling helical grooves, but in the case of the milling machine it is the short leads that impose severe stresses upon the change-gears. This is due to the fact that the milling of a short lead requires a comparatively rapid rotation of the work, since the latter must make one revolution while the table is traversing a distance equal to the lead. Attachments are made for both lathes and milling machines which are designed to overcome this difficulty.

One design of short-lead attachment for a milling machine is arranged to drive the worm-shaft of the spiral head from the main spindle of the machine, instead of from the slowly revolving feed-screw, as is done ordinarily. The feed-screw is disengaged from the power feed mechanism while using the short-lead attachment. With this arrangement, the rotation of the work is independent of the feed-screw, and the latter rotates with and is driven from the work-spindle.

Shot Peening. The impingement of metal shot or balls against the surfaces of metal parts for the purpose of cold working. This cold working increases the fatigue life of the metal parts being shot peened. The technique can be applied to parts of irregular shape without difficulty and it is also used to increase the yield strength of sheet metal and thin plate metal and the wear resistance of gear teeth. In another instance it is used for surface finishing in lieu of polishing, with a corresponding gain in fatigue strength.

The equipment used for shot peening consists of a shot projecting device which may consist of an air nozzle or a centrifugal wheel to give the shot the required velocity, a separator for removing the broken shot, a shot adding device, a work conveyor for subjecting the work to the shot for a definite work cycle, an elevator for returning the expended shot to the separator and the all important cabinet for confining the shot within the machine.

Shovel-Nose Tool. A shovel-nose tool is a tool, used in a lathe, boring mill, or similar type of machine tool, which is wider at the point than at the base where it joins the shank, and which

has a broad, flat cutting surface. It commonly is used for boring and facing pockets or recesses in the face or side of a casting or other machine part.

Shrinkage Allowance for Patterns. See Pattern Shrinkage Allowance.

Shrinkage Cracks. In castings, shrinkage cracks are due to the excessive shrinkage of the metal upon solidification, caused either by a poor arrangement of the mold, poor design of the casting, or, in certain alloys, to the extreme brittleness at a temperature just below that of solidification.

Shrinkage Fits. A cylindrical part which is to be held in position by a shrinkage fit is first turned a few thousandths of an inch larger than the hole in which it is to fit; the diameter of the latter is then increased by heating, and after the part is inserted, the heated outer member is cooled, causing it to grip the pin or shaft with tremendous pressure.

General practice seems to favor a smaller allowance for shrinkage fits than for forced fits, although in many shops the allowances are practically the same in each case, and for some classes of work, shrinkage allowances exceed those for forced fits. In any case, the shrinkage allowance varies to a great extent with the form and construction of the part which has to be shrunk into place. The thickness or amount of metal around the hole is the most important factor. The way in which the metal is distributed also has an influence on the results. Whether parts are to be assembled by forced or shrinkage fits depends upon conditions. For example, to press a steel tire over its wheel center, without heating, would ordinarily be a rather awkward and difficult job. On the other hand, pins, etc., are easily and quickly forced into place with a hydraulic press and there is the additional advantage of knowing the exact pressure required in assembling, whereas there is more or less uncertainty connected with a shrinkage fit, unless the stresses are calculated.

Tests to determine the difference in the quality of shrinkage and forced fits showed that the resistance of a shrinkage fit to slippage was, for an axial pull, 3.66 times greater than that of a forced fit, and, in rotation or torsion, 3.2 times greater. In each comparative test, the dimensions and allowances were the same. The most important point to consider when calculating shrinkage fits is the stress in the hub at the bore, which depends chiefly upon the shrinkage allowance. If the allowance is excessive, the elastic limit of the material will be exceeded and permanent set will occur, or, in extreme cases, the ultimate strength of the metal will be exceeded and the hub will burst. See Expansion Fits; also Forced Fits.

Shrinkage Rule. Except in unusual cases, a pattern-maker does not figure shrinkage by adding it to dimensions measured by the standard rule, but uses a shrinkage rule instead. These rules can be procured in all standard shrinkages; they are oversize the amount of shrinkage per foot. A two-foot rule, having an allowance equivalent to 3/16 inch shrinkage per foot, will measure 24 3/8 inches by the standard rule. These shrinkage rules do not differ in appearance from standard rules. They are graduated on the four edges in sixteenths, eighths, tenths, and twelfths.

Shrinkage Strains. Shrinkage strains are produced in castings by the solidification of some parts of it sooner than others. In a casting, the thinner sections will solidify first in the mold; when the heavier sections solidify, they often create stresses in the other sections. One way to minimize these stresses is to arrange the thickness in the various parts of the casting as far as possible so that the entire casting will solidify at the same time.

Shrink-Holes in Castings. A shrink-hole is a cavity caused by the shrinking away of the metal in cooling. This defect is most likely to occur in those parts of a casting which are excessively thick. If practicable, avoid sudden changes in the thickness of a section.

Shrouded Gears. The teeth of some cast gears are joined together at the ends by a flange or wall of metal in order to strengthen the teeth. Gear teeth which are reinforced in this way are said to be shrouded. If this shroud or supporting wall only extends to one-half of the height of the teeth, instead of to the tops, the gear is known as a semi-shrouded form.

Shunt Trip. A shunt trip is an arrangement for tripping circuit-breakers. The shunt trip has its coil normally disconnected from the circuit and trips as soon as the coil is connected in the circuit. It is generally used to trip a circuit-breaker from a distant point by the closing of a switch or similar device.

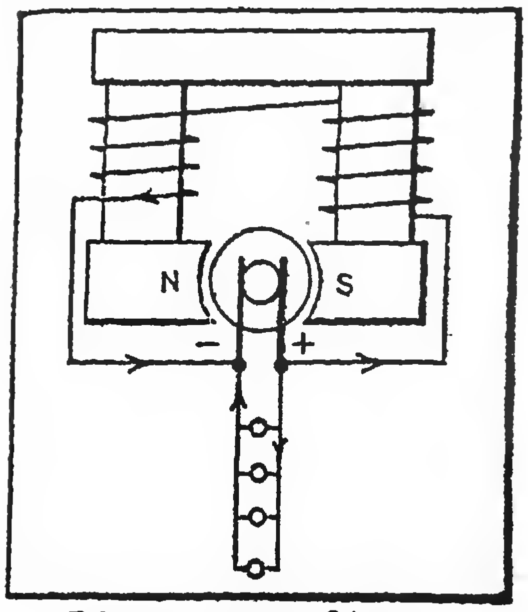


Diagram of Shunt-wound Generator

Shunt-Wound Generator. This is a direct-current generator in which the field winding is connected to the brushes of the machine and is thus in parallel with the armature winding, forming a shunt to the same, as shown by the diagram. This shunt is a comparatively fine wire of high resistance, thus limiting the field current to a small percentage of the total current, although the number of turns is proportionately higher. The voltage of such a generator is maximum at no load and, unless regulated,

decreases as the load increases. Regulation is accomplished by inserting an adjustable resistance or rheostat in the field circuit; if resistance is cut out, the field current is increased and also the voltage of the machine, and vice versa. Modern shunt-wound generators with commutating poles have a very close inherent regulation, so that a very small change is required in the position of the rheostat between no load and full load.

Shunt-Wound Motor. The shunt-wound motor is one in which the field winding is connected across the main lines, or is said to be in shunt with the armature circuit. The amount of current passing through the field is inversely proportional to its resistance, and, except in the case of the variable-speed type of shunt-wound motor, remains practically constant under all conditions of load. This results in a constant-speed motor the output of which, in horsepower, is dependent upon the current, in amperes, which passes through the armature. The characteristic of the shunt-wound motor is approximately constant speed under all conditions of load. See also Motor Selection, Direct Current.

Shut Height of Press. The term "shut height" as applied to power presses, indicates the die space when the slide is at the bottom of its stroke and the slide connection has been adjusted upward as far as possible. The "shut height" is the distance from the lower face of the slide, either to the top of the bed or to the top of the bolster plate, there being two methods of determining it; hence, this term should always be accompanied by a definition explaining its meaning. According to one press manufacturer, the safest plan is to define "shut height" as the distance from the top of the bolster to the bottom of the slide, with the stroke down and the adjustment up, because most dies are mounted on bolster plates of standard thickness, and a misunderstanding which results in providing too much die space is less serious than having insufficient die space. It is believed that the expression "shut height" was applied first to dies rather than to presses, the shut height of a die being the distance from the bottom of the lower section to the top of the upper section or punch, excluding the shank, and measured when the punch or upper section is in the lowest working position.

Sicromo. A corrosion-resistant steel for high-temperature service having at 85 degrees F. an ultimate tensile strength of 74,000 pounds per square inch with a yield point of 40,000 pounds per square inch; at 750 degrees F., 62,000 and 26,500 pounds, respectively; at 1100 degrees F., 36,500 pounds and 20,000 pounds, respectively; and at 1400 degrees F., 13,000 pounds and 7500 pounds per square inch, respectively. Suitable for applications where corrosion resistance is of major consideration, but where

conditions do not warrant the use of the higher-priced 4 to 6 per cent chromium-molybdenum steels. Especially intended for cracking-furnace tubes, vapor and hot oil lines, superheater tubes, etc.

Side Milling Cutters. A side milling cutter is provided with teeth on both sides as well as on the periphery of the cylindrical surface. Side milling cutters are used for cutting grooves or slots, as well as for many other operations. They are often used in conjunction with other forms of cutters for milling special shapes in a single operation.

Side-Tools. Side-tools are used in lathes for facing the ends of shafts, collars, etc. A right side-tool operates on the right-hand end or side of a shaft or collar, whereas the left side-tool is used on the opposite side. Side-tools are also bent to the right or left because the cutting edge of a straight tool cannot always be located properly for facing certain surfaces. See also Lathe Tools, Right- and Left-hand.

Siemens-Martin Process. The open-hearth process of making steel has been designated by various terms. In connection with the original open-hearth process (acid) developed by C. W. Siemens, pig iron was used without scrap, and ore was added to oxidize the impurities; hence, the name "pig and ore process." The addition of scrap to molten pig iron without ore was a development of the Martin brothers; consequently, the origin of the terms "Siemens-Martin process," "Martin process," and "pig and scrap process." In the United States the term "open-hearth process" is generally used, the name being based upon the type of furnace employed.

Silent Chain Transmission. The silent or "inverted-tooth" type of driving chain has the following distinguishing features: The chain passes over the face of the wheel like a belt and the wheel teeth do not project through it; the chain engages the wheel by means of teeth extending across the full width of the under side, with the exception of those chains having a central guide link; the chain teeth and wheel teeth are of such a shape that as the chain pitch increases through wear at the joints, the chain shifts outward upon the teeth, thus engaging the wheel on a pitch circle of increasing diameter; the result of this action is that the pitch of the wheel teeth increases at the same rate as the chain pitch. Another distinguishing feature of the silent chain is that the power is transmitted by and to all the teeth in the arc of contact, irrespective of the increasing pitch due to elongation. The links have no sliding action either on or off the teeth, which results in a smooth and practically noiseless action, the chain be-

ing originally designed for the transmission of power at higher speeds than are suitable for roller chains.

The efficiency of the silent chain itself may be as high as 99 per cent, and for the complete drive, from 96 to 97 per cent, under favorable conditions; from 94 to 96 per cent can be secured with well-designed drives under average conditions. While the name "silent chain" is derived from the fact that the operation is practically noiseless, the term is not applicable to other types which may run silently, but is used to designate the inverted-tooth form of chain. The distinguishing feature of different makes of silent chain is in the joint, the other characteristics being practically the same, except for variations in regard to accuracy and manufacturing methods.

Silica. Silica is amorphous silicon dioxide (SiO_2) and constitutes the greatest part of sand and sandy rocks. It occurs naturally as quartz and tridymite, which, when colored, forms some of the gem stones. When prepared artificially, it is a fine, white, tasteless, odorless powder that is soluble only in hydrofluoric acid, and is fused by alkaline carbonates. Silica, or quartz, crushed and graded to various sizes, is used in making sandpaper and sand belts, for frosting glass with sand-blast apparatus, and for other abrasive purposes. It may also be fused in the electric furnace to produce laboratory crucibles.

Silicate Bonding Process. Silicate grinding wheels derive their name from the fact that silicate of soda or water glass is the principal ingredient used in the bond. These wheels are also sometimes referred to as *semi-vitrified* wheels. Ordinarily, they cut smoothly and with comparatively little heat, and for grinding operations requiring the lowest wheel wear, compatible with cool cutting, silicate wheels are often used. Their grade is also dependable and much larger wheels can be made by this bonding process than by the vitrified process. Some of the grinding operations for which silicate wheels have been found to be especially adapted are as follows: For grinding high-speed steel machine shop tools, such as reamers, milling cutters, etc.; for hand-grinding lathe and planer tools; for surface grinding with machines of the vertical ring-wheel type; and for operations requiring dish-shaped wheels and cool cutting. These wheels are unequaled for wet grinding on hardened steel and for wet tool grinding. They are easily recognized by their light gray color.

Silicon. Silicon is a non-metallic element which exhibits three allotropic forms: amorphous, graphitoidal, and crystalline. The specific gravity of the crystalline form is 2.4. Silicon is used as a deoxidant in molten metals and also as an additive to impart certain characteristics to metals, such as hardness.

Other uses to which this semi-conductor material is put include transistors and rectifiers in the electronic field. Its melting point is 1414 degrees C.

Silicon Bronze. Silicon bronze is an alloy made from varying proportions of copper and silicon, often containing small percentages of zinc and tin. It is made by heating fluosilicate of potash, granulated glass, chloride of sodium and calcium, and carbonate of soda and lime in a plumbago crucible. This mixture, after reaction takes place, is added to molten bronze. Silicon-bronze wire has a high electric conductivity, amounting to from 40 to 98 per cent of that of copper wire, or four times greater than that of iron. Its tensile strength is also high, varying from 55,000 to 110,000 pounds per square inch. The electrical conductivity decreases as the tensile strength increases, so that wire having a conductivity of 95 per cent of that of pure copper has a tensile strength of 55,000 pounds per square inch, while wire having a conductivity of 40 per cent of that of pure copper has a strength of about 100,000 pounds per square inch. The wire resists oxidation to a considerable extent, and has been largely used for telegraph wires. Ordinary drawn and annealed copper wire has a strength of only from 30,000 to 40,000 pounds per square inch.

Silicon Carbide. This is a general class of abrasive which is produced artificially in the electric furnace; it is a chemical combination of the two elements, carbon and silicon and is given various trade names such as "Carborundum," "Crystolon," "Carbolite," "Carbolon," "Carbonite," "Carborite," "Carbowalt," "Electrolon," "Natalon," "Silicar," "Staralon," "Silizit." The principal materials used are coke, which supplies the carbon element, and sand, which supplies the silicon. The coke is crushed in a mill and is then mixed with the sand. To the mixture of sand and coke is added a quantity of sawdust, in order to make the mixture porous, thus allowing the gases to escape freely. After suitable treatment, the mass of raw material is placed in an electric furnace. The temperature of the surrounding mass of coke and sand is raised to a point between 7000 and 7500 degrees F. As the result of this high temperature, objectionable impurities in the coke and sand are destroyed or driven off in gaseous form, leaving only the carbon and silicon which unite, thus forming the abrasive, carborundum. The crystalline masses are crushed and reduced to individual crystals or grains which are carefully washed, dried, and graded through screens of different mesh, thus obtaining different grade numbers. Wheels made from this abrasive are adapted for grinding materials of low tensile strength, such as soft brasses and bronzes, cast and chilled iron, aluminum, copper, marble, granite, leather, and other non-metallic substances.

Silicones. This group of organic rubbery materials is used over a wide temperature range, from below 0 degrees F. to 600 degrees F. depending upon its form and application. Liquid silicones are used for impregnating fabrics and coating glass and ceramics to make these materials waterproof, as parting agents in molding, baking, etc., and as high-temperature lubricants. Silicones in the form of greases provide both chemical and heat resistance combined with lubrication properties. In the usual rubber-like form, the silicones are used as electrical insulation materials in the making of motors and as gasket materials where heat and chemical resistance are a requisite.

Silundum. Silundum is a trade name for silicified carbon obtained by heating carbon rods in silicon vapor in an electric furnace. Being a form of carborundum, it has the same properties; it is very hard and acid-proof and resists high temperatures. It can be heated in the air to 1600 degrees C. (2912 degrees F.) without oxidation. Silundum rods have about three times the resistance of carbon; they are used in electrical heating and cooking devices, and are made in round, flat, and square bars or tubes and in the form of grids.

Silver. Silver is the most malleable and ductile of all metals, with the exception of gold. Its specific gravity varies from 10.51 to 10.62. The average value is 10.53, making the weight per cubic inch 0.38 pound. Silver melts at a temperature of 961 degrees C. (1762 degrees F.). Its specific heat is about 0.056. Its coefficient of linear expansion per unit length, per degree F., equals 0.0000108. Its thermal conductivity is higher than that of any other metal, and is generally taken as the standard with which the heat conductivity of other materials is compared, that of silver being assumed as 100. As compared with copper, its heat conductivity is in the ratio of 100 to 74, and as compared with gold, in the ratio of 100 to 54. Silver is also the most perfect conductor of electricity, and is assumed as the standard with which all other conductors are compared, the conductivity of silver being assumed as 100. As compared with copper, its conductivity for electricity is in the ratio of 100 to 75, and as compared with gold, 100 to 73. In hardness, silver is superior to gold, but it is not as hard as copper. Fifteen grains of silver have been drawn into a wire nearly 600 feet long, and silver leaves have been beaten out to a thickness of only 0.00001 inch.

Silver-Bronze, Manganese. See Manganese Silver-bronze.

Silver Finish on Brass. A method of silvering that is applicable to such work as gage or clock dials, etc., consists of grinding together in a mortar 1 ounce of very dry chloride of silver;

2 ounces of cream of tartar; and 3 ounces of common salt. Then add enough water to make it of the desired consistency and rub it on the work with a soft cloth. This will give brass or bronze surfaces a dead-white thin silver coating, but it will tarnish and wear if not given a coat of lacquer. The ordinary silver lacquers that can be applied cold are the best. The mixture, as it leaves the mortar before adding the water, can be kept a long time if put in very dark-colored bottles, but, if left where it will be attacked by light, it will decompose.

Silver-Plating. Silver is not deposited in smooth coherent layers from all solutions. Silver deposits from a silver-nitrate solution, for example, is in a loose crystalline form, entirely useless for plating. From cyanide baths, which are universally used for silver-plating, the deposit is smooth, coherent, and of a milk-white color, which, on polishing, takes the appearance of ordinary silver. The bath may be made as follows: potassium cyanide, 98 per cent, from 6 1/3 to 7 ounces; potassium silver cyanide, crystallized, $KAg(Cu)_2$, 17½ ounces; distilled water, 10 quarts. The current density is from 1 to 4.2 amperes per square foot, at about 1 volt, and pure silver anodes are used. Silver is deposited only on surfaces of copper or of copper alloys; if other metals are to be silver-plated, a layer of copper or brass is first produced, and the silver is deposited on this. After this surface has been cleaned and pickled, it is amalgamated by immersing in a quickening solution, which is made as follows: potassium mercury cyanide, 0.9 ounce; potassium cyanide, 0.9 ounce; water, 1 quart. The object remains in this solution only long enough to acquire a uniform white coating of mercury, when it is rinsed in clean water and placed in the silver-plating bath. In order to make the silver adhere more firmly, the object is plated first for a few seconds in a striking solution with a relatively high current density, and then finished in the bath just given. The striking solution used by a prominent manufacturer of silverware is as follows: Potassium cyanide, 6 ounces; potassium silver cyanide, 0.9 ounce; water, 1 gallon. It is advantageous to agitate the solution by keeping the articles in motion while in the bath. See also Electroplating.

Silver-Ply. Mild steel sheets and plates of flange quality, bonded with stainless steel of 3 to 50 per cent of the total thickness. These sheets can be bent, spun into deep heads, deep-drawn, drilled, and otherwise worked with greater ease than solid stainless steel. Useful for manufacture of cooking vessels, storage tanks, marine equipment, and other applications where corrosion and erosion is a problem.

Silver Solder. Silver solders are made in strip, sheet, and granular form, and in a number of different grades of fusibility. The melting points of silver solders vary between 1250 and 1500 degrees F. One of the best silver solders used is made of 61 per cent silver, 29 per cent copper, and 10 per cent zinc. Many alloys of low silver content are used, in which the silver ranges from 5 to 50 per cent. Silver solder is especially suitable for jointing monel metal, nickel, and stainless steel, since it gives the necessary whiteness to the seam or joint, whereas with ordinary brazing solder, a red or yellow color is noticeable at the joint.

For successful silver soldering, it is essential that the parts be maintained throughout the operation in close, firm contact. This insures the ready flow of the solder, and results in a neat and exceedingly strong joint. Silver soldering is usually done by means of an air-acetylene blowpipe, or atmospheric gas blowpipe, and powdered borax is generally used as a flux. Borax, in paste form, is the cleanest and most convenient flux. The paste is produced by moistening the borax in clean water. The flux can be applied to the parts to be jointed with a small brush.

The work should be heated gradually at first, so as to harden the borax flux; then heating should be continued with a clean flame until a red heat is reached, at which temperature the solder will run and penetrate interstices which ordinary hard solders would fail to fill. As soon as the joint has been completed, the source of heat should be removed and the work quickly plunged in clean cold water. This method of procedure disintegrates the flux and scale which, if left to cool slowly, would set in a very hard vitreous film that is extremely difficult to remove.

Silver-White Alloy. A white metal alloy of high luster, capable of taking a brilliant polish and closely resembling silver in appearance, consists of 70 per cent copper, 15 per cent nickel, 9 per cent zinc, 4.3 per cent tin, and 1.7 per cent lead. The alloy is made as follows: The nickel is first melted with a flux of silica, and half of the copper is added gradually and mixed, after which the remainder of copper is added. The zinc is then quickly plunged beneath the surface of the molten metal which is stirred rapidly until the whole is melted. The lead and tin are added last while liquid. The metal is stirred and brought to a temperature of about 1700 degrees F., after which it is poured into ingot molds.

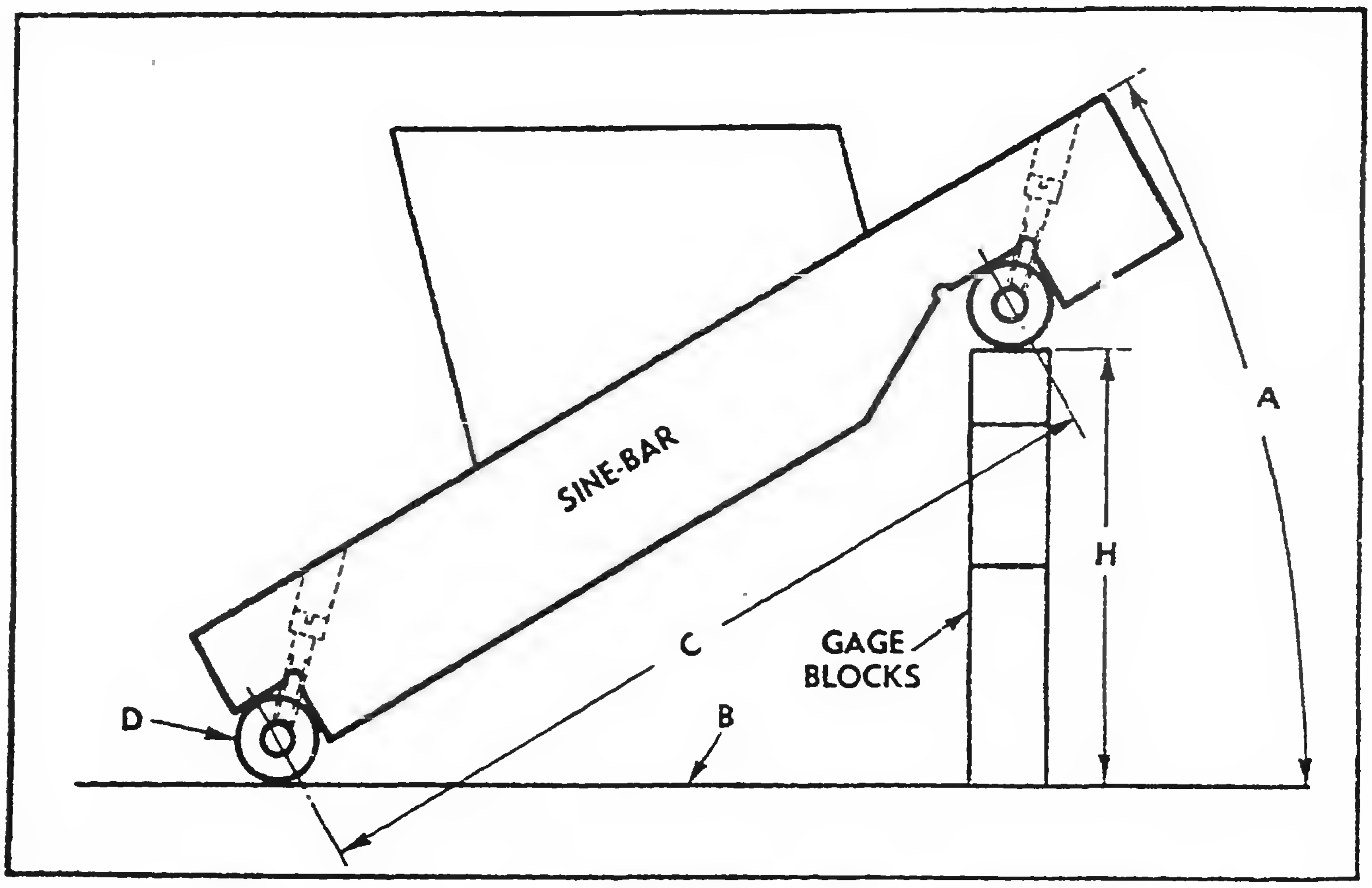
Silvery Pig Iron. See Ferrosilicon.

Sine, Arc. See Arc Sine and Tangent.

Sine-Bar. The sine-bar, or *sine-protractor,* as it is sometimes called, is used either for measuring angles accurately or for

locating work to a given angle in connection with such work as surface grinding operations on templets, gages and other angular work requiring great accuracy. Sine-bars are commonly used by toolmakers and gage-makers because they provide a very precise method of measuring or checking angles. A common form of sine-bar is illustrated by the diagram. This particular form is notched at the ends for receiving cylindrical plugs *D*. These plugs must be lapped to the same diameter and the distance *C* between their centers usually is either 5 or 10 inches to simplify the use of the sine-bar, as shown later by an example. This center distance should be as accurate as possible and the upper and lower edges of the bar should be parallel with a plane intersecting the axes of the plugs. The sine-bar is always used in conjunction with some true surface *B* from which measurements can be taken.

The angle *A* to which the sine-bar is set depends upon the height *H* of one plug above the surface *B* upon which the other



Method of setting Sine-bar to Given Angle A

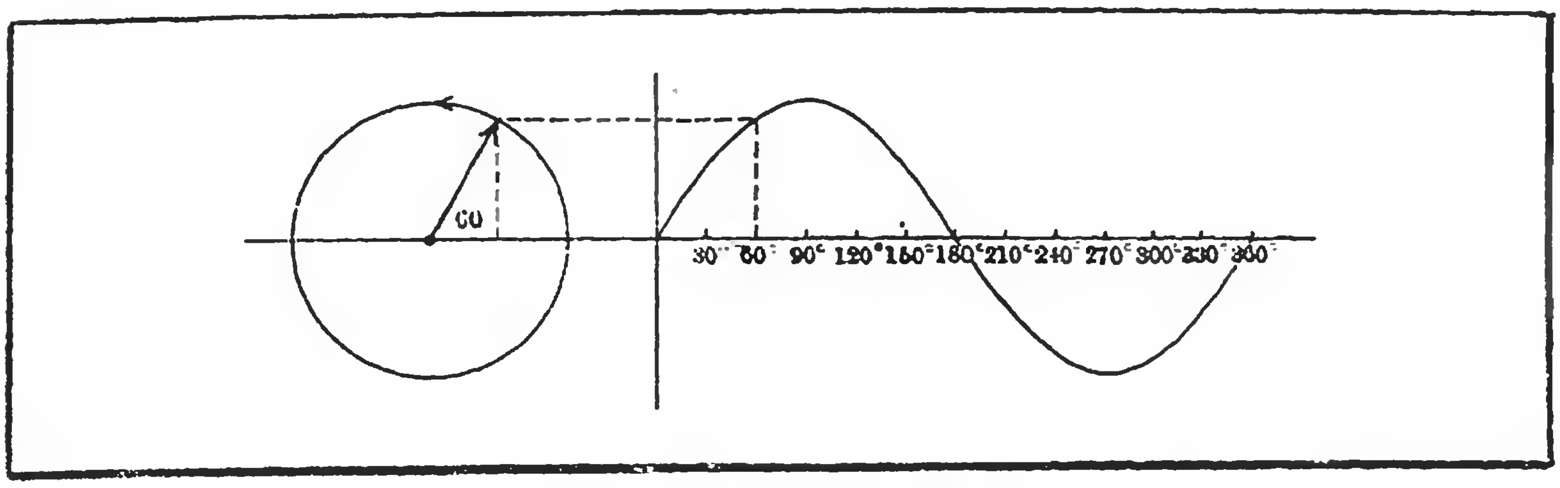
plug rests. The sine-bar frequently is set to the required height *H* by using gage-blocks to obtain great accuracy. If the sine-bar is to be set to a given angle, height *H* for this angle is determined by using the sine of the angle; hence, the name "sine-bar."

Rule: To set a sine-bar to a given angle, find the sine of this angle in a table containing the sines of angles; multiply this sine by the center distance *C* to obtain height *H*.

Sine Law. See Law of Sines and Cosines.

Sine of Angle. See Functions of Angles.

Sine Wave. The sine wave (see diagram) may be defined as follows: If, as the spoke of a wheel revolves at a uniform rate



Vector and Sine Wave

around its hub, a curve is plotted on rectangular coordinates to show the relation between the angle the spoke makes with the origin, and the distance from the end of the spoke to a horizontal line drawn through the hub, the curve so drawn will be a *sine curve.* The spoke is called the *vector* and the height of the peak of the wave is equal to the length of the vector. One revolution of the vector forms a *cycle,* which includes two "alternations" and two "half-waves," one positive and one negative. In order to specify a sine wave, it is sufficient to know the value of the vector and the number of cycles that take place per second. An alternating current not only reverses in direction, but changes to maximum and minimum values and in direction of flow according to a definite cycle, which is usually a close approximation of a *sine wave;* and, in dealing mathematically with alternating current, the cycle is assumed to be exactly a sine wave.

Single-Phase Motors. Single-phase alternating-current motors are designed for operation on a single-phase power line and most designs have some special arrangement for providing starting torque. Thus, a switch may be provided for splitting the stator winding into two parts with different reactance characteristics or an auxiliary winding is used, so that during the starting period there are two currents which are out of phase with each other flowing in the stator windings.

Single-phase motors may be grouped into several types: Capacitor, repulsion, shaded-pole, series commutator (universal) and split phase.

The *capacitor motor* has a main winding arranged for direct connection to a source of power and an auxiliary winding con-

nected in series with a capacitor. The capacitor may be connected into the circuit through a transformer and its value may be varied between starting and running. A similar type called a *capacitor-start motor* has a split-phase winding with a capacitor connected in series with the auxiliary winding. This auxiliary circuit is opened when the motor has attained a predetermined speed. The capacitor type of motor is noted for its quiet operation.

The *repulsion motor* has a stator winding arranged for connection to a source of power and a rotor winding connected to a commutator. The brushes which bear on the commutator are short circuited and are so placed that the magnetic axis of the rotor winding is inclined to the magnetic axis of the stator winding. This type of motor has a varying speed characteristic.

The *repulsion-induction motor* is a form of repulsion motor which has a squirrel-cage winding in the rotor in addition to the repulsion motor winding. In starting, the current largely passes through the repulsion winding but as the motor gets up to speed the squirrel-cage winding assumes more of the load, making for smooth starting and running. A motor of this type may have either a constant speed or a varying speed characteristic.

Similar to this is the *repulsion-start induction motor,* which has the same windings as a propulsion motor but at a predetermined speed the rotor winding is short circuited or otherwise connected to give the equivalent of a squirrel-cage winding. This type of motor has high starting torque, low starting current and constant speed. One modification of the repulsion-induction motor is designed for obtaining speed variation by shifting the brush position and is called an *adjustable-speed, brush shifting motor.*

The *series-wound universal motor* is a commutator motor in which the field circuit and armature circuit are connected in series. They are called universal motors because they may be operated on either alternating current or direct current. Their speed varies inversely with the load. They are designed for high-speed operation (5000 to 10,000 R.P.M.) and their no-load speed may reach 16,000 R.P.M.

The *shaded pole motor* is provided with an uninsulated and permanently short-circuited auxiliary winding displaced in magnetic position from the main winding.

The *split-phase motor* is equipped with an auxiliary winding, displaced in magnetic position from, and connected in parallel with the main winding. Ordinarily this auxiliary circuit is opened when the motor has reached a predetermined speed. The auxiliary winding may be used without impedance, or it may be connected in series with a reactor or a resistance, in which case the terms *reactor-start motor* or *resistance-start motor* are used.

Split-phase motors are characterized by comparatively high starting current and low starting torque so that they are used where starting is accomplished under little or no load.

Single-phase motors are widely used in fractional horsepower sizes and in some cases up to five- and ten-horsepower sizes for domestic appliance and small industrial drives.

Single-Purpose Machine Tools. Many modern developments in the machine tool field pertain to designs that are more or less special. These machines range from "manufacturing types," resembling simplified standard designs of unusual rigidity and power, to "single purpose" machines built specifically for one operation. The semi-single-purpose type of machine is now regarded favorably, particularly for certain operations in the automotive industry. Such machines, while designed for a given part, are arranged to accommodate different sizes, the idea, in some instances, being to care for possible future changes in the design of a car or other product.

Sintering. In the "powder-metal" process iron, brass, or other metal powders, almost as fine as flour, are mixed with other materials such as cobalt or copper and molded to form so-called "green compacts." These compacts are heated to white heat, but still below the melting point of the materials, by placing in a furnace or subjecting them to a very high pressure to form a hard, solid part. This heating process is called "sintering."

Sinterloy. A powdered metal that can be pressed into practically any shape and sintered to produce a dense, homogeneous steel. The forming pressure is 50 tons per square inch, and sintering is usually accomplished at 1965 to 2100 degrees F. Suitable for production of such parts as gears, cams, pump rotors, washers, pins, rivets, and splined shafts. It is said to compare well with cast steel and cast alloy steel.

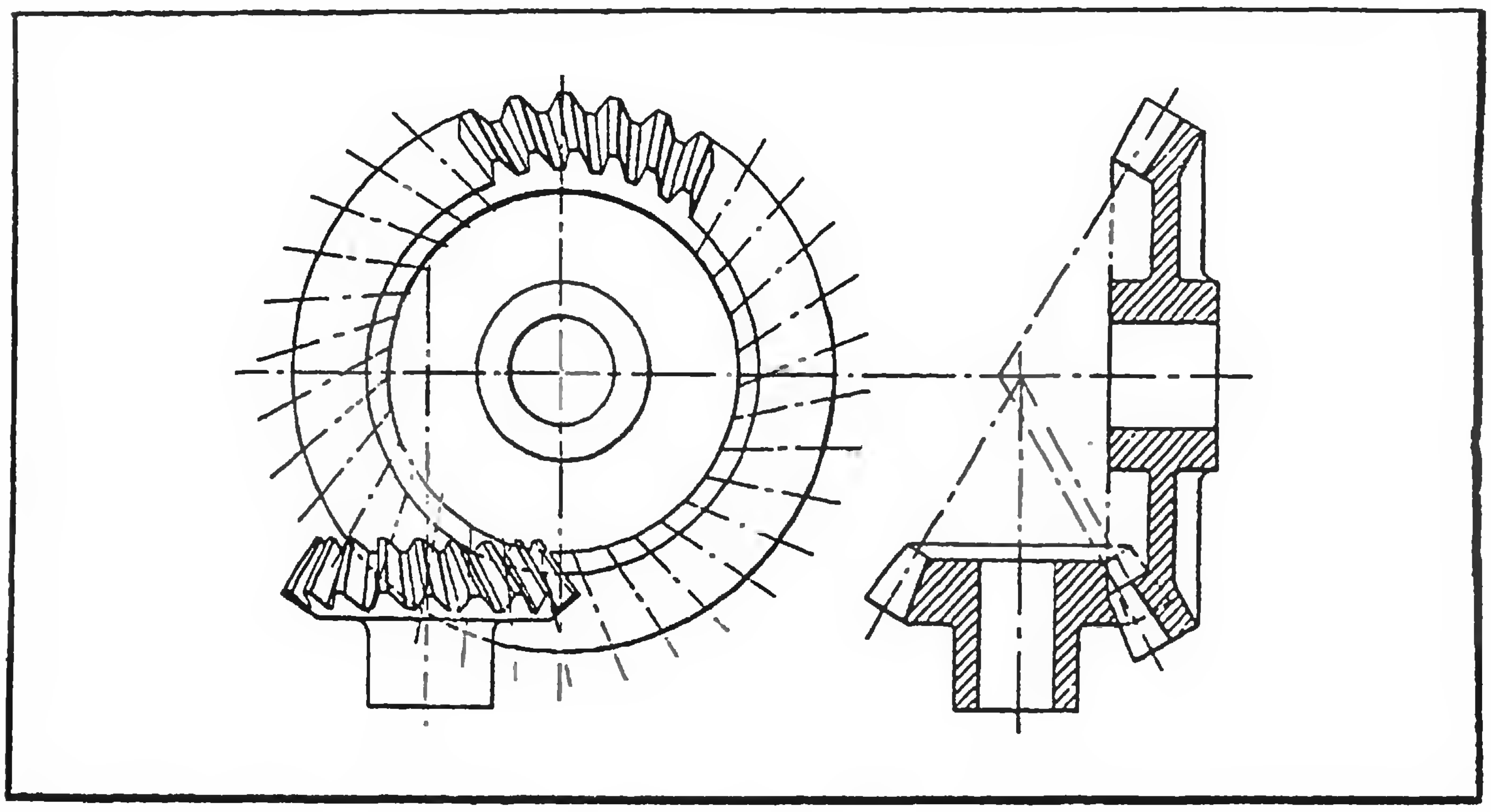
Siphon Barometer. This is an instrument used for measuring the pressure of the atmosphere. It consists of a tube bent to a U-shape, one leg of the tube being about 36 inches long and hermetically sealed at its upper end where a vacuum is formed, the remainder of the tube contains mercury. The pressure of the atmosphere is indicated by the difference between the levels of the mercury in the two vertical legs of the U-tube. See also Barometer.

Siphon-Barometric Condenser. A barometric condenser is not equipped with an air pump but is connected with a discharge or tail pipe having an elevation of at least 34 feet above the surface of the hot-well. See Condenser.

Siphon Cup. An oil cup having a wick which feeds lubricant continually to bearings by capillary action, is called a siphon cup.

Skelp Plates. The plates used in the manufacture of welded tubes and pipes are known as "skelp plates." These plates are rolled to such a width and thickness as will produce the desired diameter and strength of tubing. The edges are generally sheared for large sizes of pipe. Grooved skelp plates are rolled in mills having grooves cut into the rolls equal to the width of the plates.

Skew Bevel Gears. Skew bevel gears may be used to connect two shafts which are not parallel and which are not in the same plane, and which, in addition, are so close together that spiral or worm gearing cannot be satisfactorily applied. Skew bevel gears have straight teeth which bear on each other along a straight line, but these teeth do not converge or point to a common center, as in the case of ordinary bevel gears; they are, instead, inclined to a plane passing through the axis of the gear (see illustration). A plane through the center of the tooth intersects the axis of the gear instead of passing through the axis as in ordinary bevel gearing. For offset drives, either spiral bevel or hypoid gears are preferable to skew bevel gears. See Hypoid Gears and also Spiral Bevel Gears.



Skew Bevel Gears

Skin-Dried Molds. Green sand molds are said to be skin-dried when only the interior surface is dried. This may be done to avoid the use of dry sand or loam molds, or, in some cases, because the sand used requires drying in order to withstand the heat and "wash" of the metal. Molds that are to be skin-dried should have a facing sand that will withstand drying like a dry

sand mold. The facing sand is backed with ordinary heap or floor sand.

Skull Cracker. A drop weight, used for breaking scrap castings, etc., into smaller pieces, is called a skull cracker. The spherical weight or ball is hoisted above the scrap and released by pulling a rope attached to the releasing latch or trigger.

Slab. A "slab," according to the usage of the term in rolling mill practice, is flat and at least 2 inches thick and 12 inches wide.

Slabbing Machines. Horizontal milling machines of the planer type are often termed *slabbing machines*, especially when they are used chiefly for the milling of plane surfaces or for "slabbing" operations. Some manufacturers classify their slabbing machines as vertical or horizontal types, depending upon the position of the milling spindle or spindles, as the case may be. Others do not distinguish between the horizontal and the vertical types, but apply the name "slabbing machine" regardless of the position of the spindles. Rotary planers are sometimes called slabbing machines.

Slack of Screenings. This is a finely pulverized coal which passes through a screen of 3/16 inch mesh. This coal is often known as culm or culm coal and is frequently used in power plants.

Slag Cement. A cement made by mixing granulated basic blast furnace slag and hydrated lime and then grinding the mixture. It is the same as Pozzuolanic cement.

Slavianoff Welding Process. This electric welding process is a modification of the Bernardos arc process. Instead of using a carbon electrode, the electrode is of the same material as the metal to be welded, this change being made in order to prevent the hard welds which sometimes result with the Bernardos or Zerener processes, owing, principally, to the transfer of carbon from the electrode to the weld.

Sledge Hammers. The weight of sledge hammers varies according to the size and weight of the work for which they are used; some hammers only weigh 8 pounds, while others weigh 20 pounds or over. Smaller hammers of the same pattern, weighing less than 8 pounds, are called *quarter hammers*, and those used for the very lightest work, generally are made with a ball-peen like a hand hammer and are called *backing hammers*.

Slenderness Ratio. See Ratio of Slenderness.

Slide-Rest Development. Devices for clamping metal cutting tools in a fixed position were employed comparatively early, but the first record of the slide-rest dates from 1772. Complete drawings and details of an excellent slide-rest were given in that

year in a French encyclopedia. As early as in 1741, Hindley, a York clockmaker, produced a screw-cutting lathe with change-gears. This was a very small machine used in the clock-making trade only. None of these early developments, however, have had any commercial importance, or, apparently, any direct influence on the development of machine tools. The real foundation of modern machine tools was laid about 1794 by Maudslay who developed the first slide-rest to receive general practical application. Apparently Maudslay was not acquainted with the French slide-rests that had been in use previous to 1772, and, on account of the development that has followed the design of slide-rest made by him, the credit for the development of the slide-rest is generally given to Henry Maudslay, of London. Up to about the time of Maudslay's design of slide-rest, the best lathes in existence were substantially like the present pattern-makers' speed lathe, having a light headstock and tailstock, and an adjustable rest for a hand tool, which was used for metal as well as for wood. Any refinement that had been made in previous years belonged apparently only to very small machines used by clockmakers, who in those days seemed to have the monopoly in mechanical ingenuity. About 1800, Maudslay provided his lathe with lead-screw and change-gears, in addition to a slide-rest, and from then onward the development of the modern machine tool has been continuous and rapid.

Slide-Rest of Compound Type. The compound type of slide-rest for lathes has angular adjustment in a horizontal plane and it enables a tool to be fed at right angles to the lathe bed, parallel with it, or at any intermediate angle. There is a lower slide which is adjustable at right angles to the ways of the bed, and an upper slide which may be set in any angular position for boring taper holes, turning taper surfaces, etc. The circular base of the upper slide is graduated in degrees.

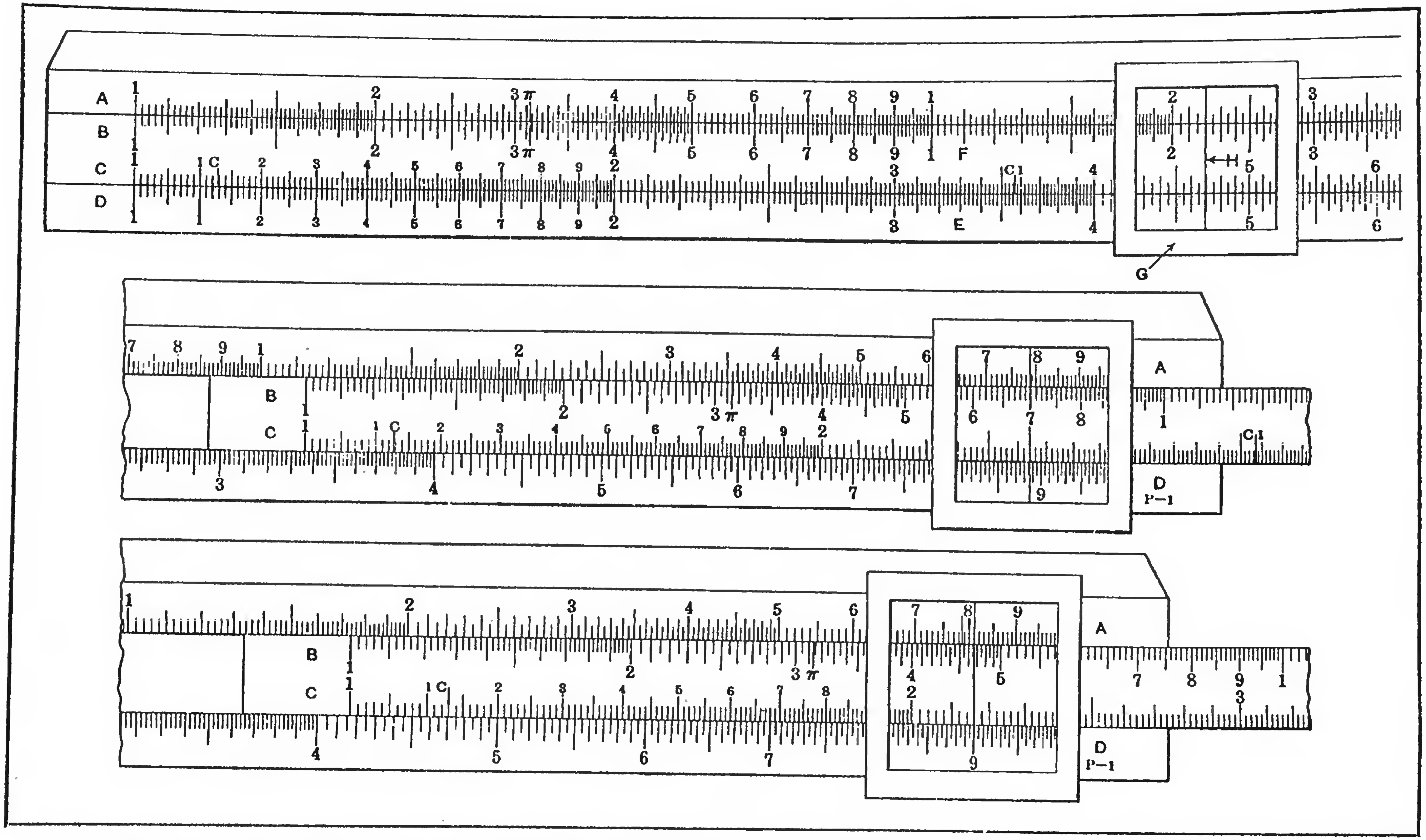
Slide-Rule. The slide-rule is an instrument by the aid of which various calculations may be made mechanically, with greater ease and rapidity than by ordinary arithmetical means, and usually with a sufficient degree of accuracy to meet all practical requirements. It is used most extensively for performing multiplication and division of numbers, but it may be used for finding powers, roots, logarithms, and trigonometric functions, and for various other purposes. The operation of a slide-rule is based on the use of logarithmic scales. Those who are familiar with logarithms will recall that to multiply two numbers together it is only necessary to take the logarithm of each number, add them together and find the equivalent number (anti-log) represented by the resulting total logarithm. This multiplication

of numbers by the addition of their logarithms can be readily accomplished with the aid of suitable logarithmic scales. Thus, if a scale were laid out on paper so that the distance from the beginning of the scale to any number on the scale is equal or proportional to the logarithm of the number, one could, by adding the distance of one number from the beginning of the scale to the distance of another number from the beginning of the scale (which would, in fact, be adding together the logarithms of the two numbers) read their product directly on the scale. This was actually done by Gunter in 1620 who laid out a logarithmic scale and used dividers to add up the scale distances or in other words to multiply the scale numbers. In 1627 these logarithmic scales were drawn by Wingate on two separate wooden rules sliding against each other so that the use of dividers was unnecessary and in 1657 Partridge brought out the slide rule in its present form.

Construction of Slide Rule: In its most common form, as shown in the upper diagram, the slide-rule is a rule about 11 inches long, 1½ inches wide, and ⅜ inch thick, and consists of three main parts: The body *E*, usually referred to as the rule; the slide *F*, which has tongues that fit into grooves in the body and thus allow it to be moved smoothly and easily in either direction; and the runner *G*, sometimes called the "cursor," which is a light metal frame that may be slid endwise along the rule and that carries a plate of glass about one inch square, on the under surface of which is a fine scratch *H*, called the "hair-line." This line is at right angles to the direction of motion of both the slide and the runner, no matter where the runner is placed along the rule. A tongue that fits a groove in the bottom edge of the rule holds the runner to the rule, and a light spring that bears against the upper edge keeps the runner snugly in place.

The upper faces of the rule and slide are inscribed with suitable logarithmic scales which, in the common form of rule, are designated as *A*, *B*, *C*, and *D*, as illustrated. Scales *C* and *D* are exactly the same and are used in combination for the operations of multiplication and division.

Multiplication and Division: Thus, as shown in the middle diagram, when one end of the scale *C* is set at some figure on the *D* scale, say 3.36, it is actually at a point which is a proportional distance from the left end of the *D* scale equal to the logarithm of 3.36. Now if the cursor is moved to some number on the *C* scale, say 2.64, it will actually be a proportional distance from the left-hand end of the *C* scale equal to the logarithm of 2.64 or at a proportional distance from the left-hand end of the *D* scale equal to the logarithm of 3.36 plus the logarithm of 2.64. The *D* scale reading of 8.87 at this point is, therefore, equal to the



(Upper diagram) Component parts of a slide rule. (Middle diagram) Multiplying 3.36 by 2.64.
(Lower diagram) Dividing 9.00 by 2.16

product of 3.36 times 2.64. In division, this operation is performed in reverse. As shown in the lower diagram, the divisor 2.16 on the *C* scale is set against the dividend 9.00 on the *D* scale. The left-hand end of the *C* scale is now at a proportional distance from the left-hand end of the *D* scale equal to the logarithm of 9.00 minus the logarithm of 2.16 and the reading at this point on the *D* scale is equal to 9.00 divided by 2.16 or 4.16.

Squares and Square Roots: The logarithmic *A* and *B* scales, which are exactly the same, are called square root scales and they are so laid out that any point on the *A* scale has a logarithmic value equal to twice that of a point which is directly below it on the *D* scale. (The same relation holds true with respect to points on the *B* scale compared with points directly below on the *C* scale.) Thus if the cursor hair-line is set on any number on the *D* scale it will indicate the square of that number on the *A* scale. This is based on the fact that to find the square of any number you multiply its logarithm by 2 and find the corresponding number (anti-log) of the resulting logarithm. In corresponding manner by setting the cursor hair-line at some number on the *A* scale the square root of that number can be immediately read where the hair-line crosses the *D* scale directly below. The *A* and *B* scales virtually repeat themselves so that on each, a complete scale from 1 to 10 extends from the left hand end to the middle and another complete scale from 1 to 10 extends from the middle to the right-hand end. Here the problem arises as to which scale should be used in finding the square root of a given number. The left-hand scale is used where the number has an odd number of digits, if it is an integer, or an odd number of zeros immediately following the decimal point, if it is a decimal of less than 1. The right-hand scale is used where the number has an even number of digits, if it is an integer, or no zeros or an even number of zeros immediately following the decimal point, if it is a decimal of less than 1. For decimals greater than 1, the rule for integers is followed and only the digits to the left of the decimal point are counted.

Scale Values: The scale numbers on a slide rule may be assigned arbitrary values equivalent to any multiple of ten. Thus the number 4 on the scale may stand for 0.04; 0.4; 4; 4,000; 4,000,000; etc. However, when a given multiple is used in any calculation it must be applied to all settings and scale readings for that calculation. Usually, a slide rule of this type and size is considered to be accurate to three places, i.e., the first three significant figures of any number, although in many cases the third figure in a reading or setting may be an estimate.

Types of Slide Rules: More extensive slide rules are available which provide scales for finding any root or any power of a num-

ber; for solving special equations such as $\sqrt{x^2 + y^2}$ at one setting; for finding the values of various trigonometric functions or to perform a variety of special mathematical operations such as stadia slide rules for calculating horizontal distance and vertical height when the rod reading and elevation of telescope are known; horsepower slide rules for obtaining the indicated horsepower of an engine and hydraulic rules for finding the velocity of the flow of water through pipes. Slide rules of circular shape, which afford greater compactness, or of cylindrical shape, which afford greater accuracy, are also available.

Slide Valve. The simplest form of valve for steam engines is that known as the *plain slide valve*. Fig. 1 shows a longitudinal section of a slide valve with the ports, bridges, etc. The valve is shown in mid-position in order that certain points relating to it may be more easily understood. The valve V consists of a hollow casting, with ends projecting beyond the ports as shown; the lower face is smoothly finished and fitted to the valve seat AB.

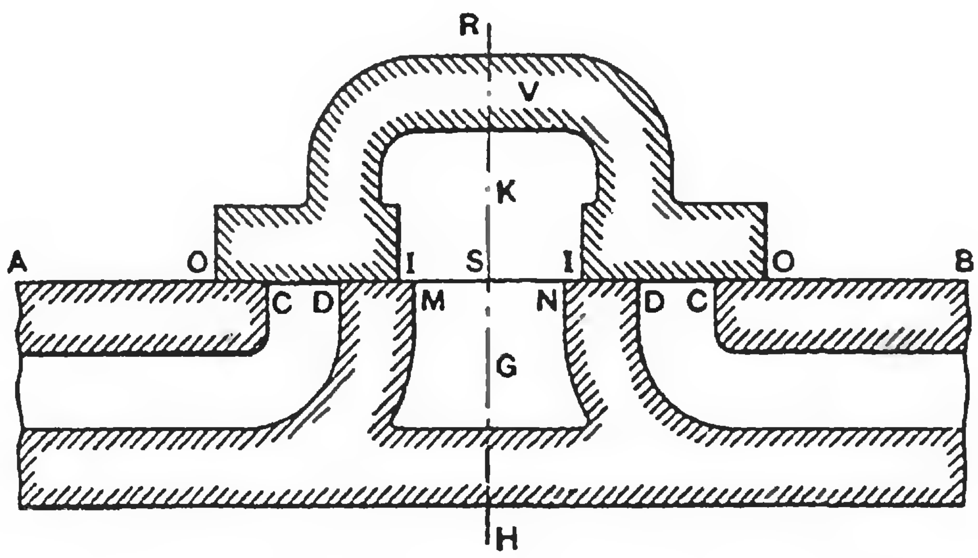


Fig. 1. Longitudinal Section of a Steam Engine Slide Valve and Ports

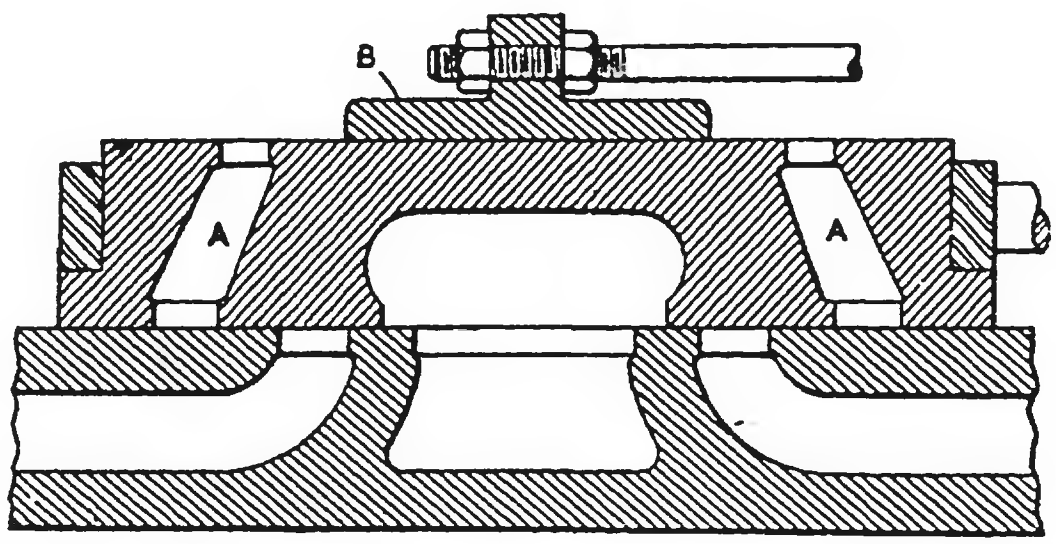


Fig. 2. Slide Valve having Auxiliary Cut-off Valve

In operation, it slides back and forth, opening and closing the ports which connect the steam chest with the cylinder. Steam is admitted to the cylinder when either port *CD* or *DC* is opened, and is released when the ports are brought into communication with the exhaust port *MN*. This is accomplished by the movement of the valve, which brings one of the cylinder ports and the exhaust port both under the hollow arch *K*. The portions *DM* and *ND* of the valve-seat are called the bridges. It will be seen that the portions *OI* and *IO* are wider than the ports which they cover. This extra width is called the *lap*, *OC* being the *outside lap* and *DI* the *inside* or *exhaust lap*. The object of the outside lap is that the steam may be shut off after the piston has moved forward a certain distance, and be expanded during the remainder of the stroke. If there were no outside lap, steam would be admitted throughout the entire stroke and there would be no expansion. If there were no inside lap, exhaust would take place throughout the whole stroke, and the advantages of premature release and compression would be lost. Hence, outside lap affects the cut-off, and inside lap affects release and compression.

Balanced Slide Valve: Many of the slide valves now in use are of the balanced type, which means that the steam pressure is excluded from most of the upper surface of the valve to reduce the pressure on the valve seat and the resistance to movement. There are different designs of balanced valves.

Riding Cut-off Valves: If a steam engine is equipped with a single slide valve, any change in the point of cut-off will cause a corresponding change in the point of admission, thus varying the lead, release, and compression; hence, on many modern engines, the cut-off is varied independently by a separate auxiliary valve. The type of cut-off valve commonly used slides upon a bearing surface of the main or distribution valve, and, therefore, is often referred to as a "riding" valve. The main valve is operated by a fixed eccentric, and the riding valve by the eccentric of a shaft or flywheel type of governor, which varies the point of cut-off automatically, according to speed. For instance, if the engine speeds up, the position of the eccentric is changed with relation to the crank, so that the steam is cut off earlier, thus decreasing the speed, whereas, if the engine slows down as the result of an increase in load, the cut-off occurs later, which increases the power and brings the speed back to normal. This action of the governor, however, does not affect the operation of the main valve.

A simple form of riding cut-off valve is shown by the sectional view, Fig. 2. The main valve contains ports *A*, through which the steam is admitted to the cylinder, and the riding valve *B* serves to cut off the steam. The latter may be controlled by any of the

different types of shaft governors in common use. Another valve mechanism which operates on the same principle, differs considerably in form, as both the main and cut-off valves are cylindrical, the cut-off valve working within the main valve. The inner or cut-off valve is operated by the eccentric controlled by the governor, and the main valve by the separate eccentric attached to the main shaft.

When setting riding or auxiliary cut-off valves, the general practice is to set the main valve the same as an ordinary slide valve, or so that it has equal port openings or lead at each end of the stroke, assuming that there is lead. The riding valve is usually set to give an equal cut-off for the forward and return strokes. When the riding valve is controlled by a shaft governor, which is the method commonly employed, the cut-off is equalized either at the middle of the range of the governor or at the point where it is expected that the engine will run most of the time. The exact method of procedure in setting the valves on engines of different design depends somewhat upon the arrangement of the valve-gear and governing mechanism, in each particular case.

Slim Taper File. Slim handsaw taper or slim taper files are like the ordinary handsaw files, but considerably lighter. They have largely superseded the regular handsaw files, the principal advantage being the greater sweep or stroke obtainable from the same section. There is also the *extra-slim taper* which is of lighter stock than the slim taper. Handsaw files are sometimes made in a blunt shape.

Slings. Slings are used in connection with hoisting apparatus for lifting loads and they are made either of chains, wire rope, or manila rope. Of these, chain slings are probably the most commonly used, but wire rope is employed at the present time more than formerly, and there are certain conditions under which manila rope is preferable.

Slip. The slip of an induction machine is the difference between its synchronous speed and its operating speed. Slip may be expressed (a) as a percentage of synchronous speed; (b) as a decimal fraction of synchronous speed; or (c) directly in revolutions per minute.

Slitting Cutters. Metal slitting cutters or slitting saws are used for cutting off stock or for milling narrow slots, like the screw-driver slots in screw-heads, and for similar purposes.

Slitting Files. A slitting file is a type that is similar to the feather-edge, although the taper is less abrupt and the edges are sharper.

Slotting Attachment. A slotting attachment is sometimes used for adapting a milling machine to slotting. The tool-slide, which has a reciprocating movement like the ram of a slotter, is driven from the main spindle of the machine by an adjustable crank which enables the stroke to be varied. These varying strokes are indicated by a graduated scale on the front of the attachment. When the attachment is in use, a slotting tool of the required shape is clamped to the end of the slide. The slide swivels about the machine spindle and can be set at any angle from the vertical to the horizontal without affecting the length of the stroke. The setting is indicated by graduations on the side of the swivel-head. These angular adjustments are especially desirable when slotting out dies, in order to obtain the necessary clearance. Attachments of this type are largely used in connection with diemaking and tool-making, for slotting out small blanking dies, box tools for screw machines, etc.

Slotting Machines. The slotting machine or "slotter," as it is commonly called, operates on the same general principle as a shaper, except that the ram which carries the planing tool moves in a vertical direction and at right angles to the work-table. Slotters are used for finishing slots or other enclosed parts which could not be planed by the tool of a horizontal machine like a planer or shaper. The slotter is also used for various other classes of work requiring flat or curved surfaces which can be machined to better advantage by a tool which moves vertically. The slotting machine was originally designed for cutting keyways in pulleys, but practice soon demonstrated the adaptability of this machine for other branches of work. Therefore, while the primary purpose of the machine has been changed, the original name is still retained. The additional name applied to slotting machines usually indicates the design of the driving mechanism, or the nature of the work for which the slotter is used in case of special machines; thus there are *crank slotting machines* which have a crank drive, *geared slotting machines* which are equipped with gearing instead of a crank-driving mechanism, whereas *die slotters* and *locomotive frame slotters* are examples of the special machines designed for certain classes of work. See also Die Slotters.

Slush-Castings. The process known as slush-casting is employed extensively in the production of ornamental objects made of spelter or zinc. In this process the metal in the mold is poured back into the ladle as soon as a thin layer next to the mold has set; thus hollow and, therefore, relatively light castings are produced. The molds used are of metal, usually bronze or brass, which can be machined evenly and which will not be injured by

the molten metal. The process is substantially as follows: The metal is poured into the hollow mold until it is full, and then the mold is immediately emptied, leaving a thin-walled casting chilled upon the inside surface. The mold is usually mounted upon trunnions or otherwise arranged to facilitate rapid emptying. Because of the extensive use for ornamental purposes, castings so produced are often plated, stained, or treated in other ways to produce color effects.

Slushing Oils. Slushing oils are materials used for protecting bright metal where it is not feasible to use paint, varnish, or other fixed coatings. An ideal slushing oil is one that can be easily applied to all kinds of metal surfaces by a variety of methods. It should coat the surfaces with a sufficiently thick and impervious film to exclude moisture and air (to prevent rusting), should remain in position for an indefinite length of time, and yet be completely removable from the surface without undue labor. The material should itself have no corrosive action on any kind of metal.

Small Tools. The expression "small tools" is generally used in the metal-working industries and is understood to mean such tools as taps, dies, reamers, milling cutters, drills, and counterbores; but the expression is not descriptive and it has been proposed that tools of this kind be called "metal-cutting tools," and the industry making them, the "metal-cutting tool industry." The latter name appears to be sufficiently descriptive. It has a definite meaning, not only within the machine-building industry, but also outside of that field.

Smelter Coke. This is a coke fuel containing more than 1.2 per cent of sulphur and, therefore, not used for the smelting or melting of iron or steel, but often employed in the smelting of non-ferrous ores.

Smelting. Smelting is the process of obtaining a metal from its ore by means of melting the ore and reducing the impurities, so that a nearly pure metal is obtained.

Smyrna Emery. Smyrna emery, also known as Turkish emery, is an abrasive obtained from the vicinity of Smyrna in Asia Minor. The value of the emery as an abrasive depends on the percentage of crystalline aluminum oxide that it contains. Smyrna emery contains about 57 per cent of this material, and, hence, is not as good as the best emery obtainable, that from Naxos, which contains 63 per cent.

Snagging Castings. The removal of gates, sprues, fins, or other projections on castings, either by grinding or chipping and filing, is commonly known as "snagging." Grinding wheels are

ordinarily used for this work, especially in foundries and wherever castings are produced in large quantities. The type of grinder that should be used for this work depends upon the size and shape of the castings. In general, castings weighing less than from 50 to 75 pounds are ordinarily ground on grinders of the floor-stand type or disk grinders, whereas heavier castings are ground either by swinging-frame or flexible-shaft grinders, because, when the castings are large and heavy, it is much more convenient to move the grinding wheel over the casting than to present the work to the wheel. When a floor-stand type of grinder is used, the castings are ordinarily supported on rests while being ground. In some cases, however, ordinary work-rests are not suitable, and it is preferable to support the castings by a chain or hoist suspended from an overhead trolley. Disk grinders are usually equipped with adjustable fixtures, and are used principally for grinding castings that are fairly uniform in size.

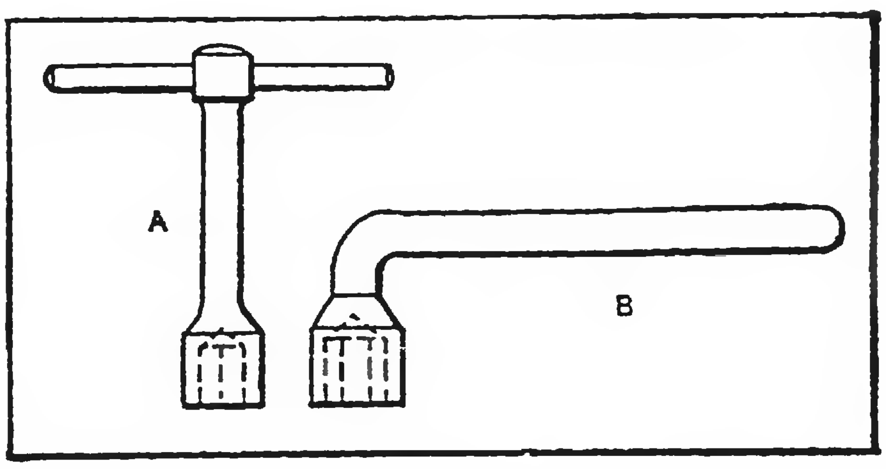
Snap Flasks. See Flasks for Molding.

Snub Pulley. This is a pulley used in a belt conveyor installation to support the returning idle part of the belt.

Soaking. When steel is kept in a furnace in order to insure thorough and uniform heating at a given temperature, this is commonly known as "soaking," the steel being allowed to "soak" at whatever temperature is required. In steel mills, a soaking pit is an underground furnace in which ingots are placed to obtain a uniform temperature preparatory to rolling.

Soapstone. Same as Talc.

Socket Wrenches. Wrenches of this type are so named because the nut end is in the form of a socket. The *single-head straight socket wrench A* is made for confined situations, as in a hole, or in any other position where a wrench of the ordinary kind could not be used. In tightening jaws on a chuck, when the heads of the bolts are set flush, this type is generally used. It may be machined at the nut end for either hexagon or square-head bolts. The *offset socket wrench B* is useful in many cases for setting up bolts or nuts when the slipping of an ordinary wrench might break some part, or when the position of the bolt is such that it would be difficult to reach it with the ordinary type of wrench.



Socket Wrenches

Soda Cleaning Solution. A soda solution which may be used for removing oil or grease from machine parts should contain about one-half pound of sal soda to each gallon of water. If old paint is to be removed, the solution should consist of about one-quarter pound of caustic soda to each gallon of water. As caustic soda is a strong alkali, care should be taken to prevent it from getting onto the hands. These solutions should be heated to the boiling point before immersing the parts to be cleaned; then the work will dry quickly after being removed, and will not rust. A wire basket or perforated bucket is convenient for washing small pieces. The time required for cleaning depends somewhat upon the nature of the grease and to what extent it has dried and hardened.

Soda ash, the chemical formula of which is Na_2CO_3, has largely superseded potash solutions for cleaning purposes, because it is cheaper and, for most work, better than potash. The value of soda ash and potash solutions for cleaning purposes is that these chemicals combine with grease and, therefore, act as cleansing agents.

Sodium. Sodium is one of the metallic elements belonging to the alkali metal group, the chemical symbol of which is Na, and the atomic weight, 23.0. It is an element found abundantly in nature, but always in combination with other elements. Sodium possesses a silvery color, but, if exposed to the air, the surface is rapidly covered with a layer of hydroxide. The specific gravity is 0.98, making the weight per cubic inch 0.035 pound. Sodium melts at a temperature of 97 degrees C. (207 degrees F.), and boils at about 875 degrees C. (about 1600 degrees F.). The specific heat at 32 degrees F. is 0.293. At ordinary temperatures, sodium is as soft as wax and can be cut with a knife, but it hardens at very low temperatures. It ranks next to silver, copper, gold, and aluminum as a conductor of electricity, its electrical conductivity (silver = 100) being 32. It burns on heating in air with a yellow flame. With potassium, sodium forms a liquid alloy resembling mercury, which has been employed in high-temperature thermometers.

Sodium Cooling of Exhaust Valves. Excessive heating of exhaust valves, particularly in aircraft engines, reduces greatly the valve life and has resulted in the development of special means of cooling. The exhaust valve temperature increases with both engine speed and valve diameter. Aircraft engines not only operate at high speeds but also have larger bores than other high-speed engines and, consequently, require larger valves. Owing to its comparative length and small cross section, the valve stem naturally offers considerable resistance to heat flow; hence, the idea of improving the heat-flow conditions by forming a cham-

ber in the stem and partly filling this chamber with a liquid of high heat capacity, which would be reciprocated therein by the alternate opening and closing motions of the valve.

The search for an effective cooling medium finally led to the adoption of metallic sodium, which has a much lower melting point (208 deg. F.) and a much higher boiling point (1615 deg. F.) than the salts previously used and whose specific gravity is less than one (sodium floating on water). In the early internally cooled valves only the stems where hollow, but at present both the stem and head are made hollow; hence, the cooling medium comes closer to all points at which heat is absorbed, and the cooling action is more effective. At present practically all aircraft engines of more than 300 horsepower have sodium-cooled valves, and such valves are used also in certain other heavy-duty engines.

Sodium Cyanide. When steel is heated in a salt bath preparatory to hardening, sodium cyanide is often used. See Salt Baths for Heat-treating Operations.

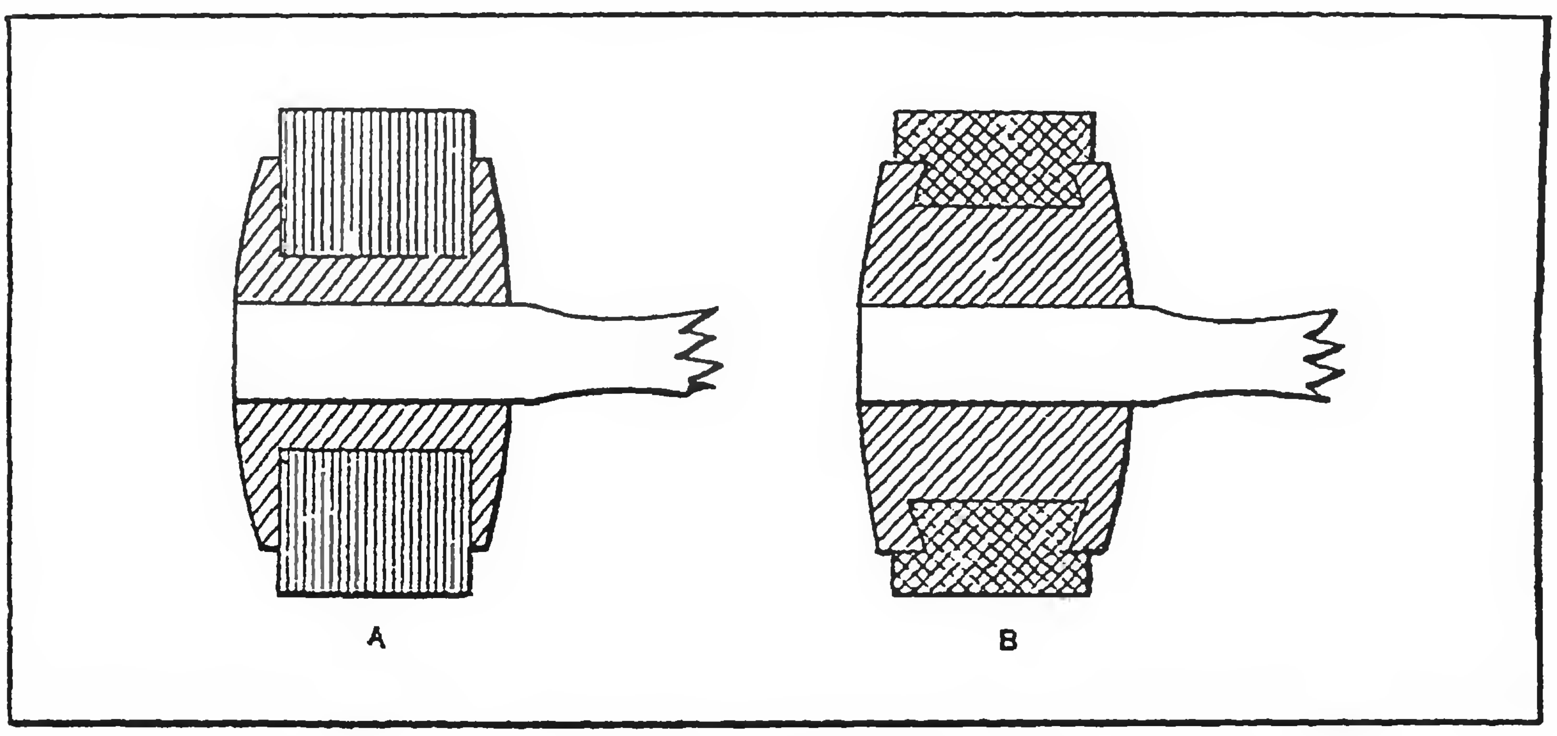
Sodium Vapor Lamps. See Vapor Lamps.

Soft Coal. This coal contains from 50 to 75 per cent carbon and a large percentage of volatile matter, varying from 25 to 50 per cent. It is the same as Bituminous Coal.

Soft Coke. Soft coke, also known as heating coke or jamb coke, is the coke obtained next to the back and front of the coke oven and around the oven doors when producing regular foundry and furnace coke.

Softening Plants for Water. See Water Softening Plants.

Soft Hammers. "Soft hammers" are used in machine shops either to prevent marring finished surfaces or to avoid upsetting



Soft Hammers or Mallets

the ends of arbors, bolts, etc. Soft hammers are made of copper, babbitt metal, rawhide, or brass. A rawhide hammer is illustrated at *A* in the accompanying illustration. In this particular case the rawhide heads or faces are inserted in pockets formed in the body of the hammer, so that they may readily be renewed. Diagram *B* illustrates a babbitt metal or lead hammer. In this case the lead or babbitt metal faces are held in the dove-tailed pockets shown. While a heavy blow may be struck with one of these soft hammers, a finished surface will not be marred by dents, because of the relative softness of the hammer face.

Soil Load Capacity. See under Foundations for Machinery.

Soil Weight Per Cubic Foot. See Earth or Soil Weight.

Solder, Brazing. See Brazing, Spelter Solder.

Solder, Cadmium. See Cadmium Solder.

Soldering. Soldering is a process of joining metals together by means of an alloy which is melted into the joint, after the application of a suitable flux, and unites with the metals. The solder has a lower melting point than the metal to be joined. There are two general methods of soldering, namely, soft soldering and hard soldering. Ordinarily, soft solders are used when soldering with a heated copper bit or "iron" and the solder is an alloy of tin and lead, which melts at comparatively low temperatures. Hard solders are alloys of silver, copper, zinc, etc., and melt at very much higher temperatures than the soft solders. The hard soldering of copper, iron, etc., is generally known as *brazing*, and the solder, as *spelter*.

Solder: Solder is almost always composed of an alloy of two or more metals. The solder used should have a lower melting point than the metals to be joined by it, but the fusing point of the solder should approach as nearly as possible to that of the metals to be joined so that a more tenacious junction is effected. *Soft solder* consists chiefly of lead and tin, although other metals are occasionally added to lower the melting point. The fusibility of lead-tin alloys increases with the percentage of tin up to a certain point, but when the tin exceeds 67 per cent, the melting point rises gradually to the melting point of tin. Soft solders are termed common, medium, and fine, according to the tin content, those containing the most lead being the cheapest and having the highest melting points. Fine or "best" solder is largely used for soldering Britannia metal, brass, and tin-plate articles. The soft solder called "common" is used by plumbers for ordinary work, this solder containing two parts of lead to one part of tin. Fine solder is also used for soldering cast iron, steel, copper, and many alloys. Solder composed of two parts of lead and one part

of tin is termed, in England, "plumbers' sealed solder." *Hard solders* for brazing are composed of copper and zinc, the composition varying according to the metal to be brazed.

Strongest Soft Solder: Tests of tensile strength, based upon cast bars, sticks, and wires, indicate that the higher the tin, up to 73 per cent tin and 27 per cent lead, the greater the breaking strength. In the case of two pieces of tinned steel soldered together, the maximum strength is obtained with a solder containing about 60 per cent tin. Experience has shown that the strongest mixture for general soldering purposes is a solder composed of 57 per cent tin and 43 per cent lead, particularly if ¼ to ½ per cent of antimony is added to the mixture. For mechanical soldering, 45 per cent should be the highest tin content, and for most dipping bath work, it has been demonstrated that tin from 35 to 40 per cent, according to the nature of the work, will give ample satisfaction, provided the solder is properly made.

Solder Wire: The term "solder wire" is applied to wire which is extensively used in the manufacture of jewelry and which consists of a metal suitable for forming such objects as chain links, etc., and of a solder embedded in the wire either as a solid core or otherwise, to serve as the binding element. Metals commonly used in the manufacture of solder wire are pinchbeck, German silver, tin and so-called platinin and goldin metal, as well as gold and silver. Pinchbeck is the name applied to certain alloys which are closely related to brass alloys but contain less zinc. Common classes of pinchbeck alloys include similor, mannheim gold, oveide and chrysorin.

Solder for Aluminum: According to investigation by the Bureau of Standards, solder for aluminum should consist of a tin base with an addition of zinc, or zinc and aluminum. The function of the alloys is principally to produce a fluid mixture within the range of soldering temperatures. A high temperature is advised to secure adhesion of the tinned surface. For tin-zinc solders, the following composition is suggested: Zinc, 15 to 50 per cent, and the remainder tin. For tin-zinc-aluminum solders, the composition suggested is: Zinc, 8 to 15 per cent; aluminum, 5 to 12 per cent; and the remainder tin. By using the higher values of the zinc and aluminum percentages, the solder will be too stiff at the lower temperatures to flow readily. A higher temperature will secure a better joint. Solders should be applied without a flux after preliminary cleaning and tinning of the surfaces to be joined. Good aluminum solder should not be brittle. The tensile strength of the better grades of aluminum solder is about 7000 pounds per square inch. The strength of the joint, however, is dependent upon the workmanship. All metals used for aluminum soldering are electrolytically negative to aluminum. A soldered

joint for this reason is attacked by electrolysis and destroyed when exposed to moisture; hence, it is recommended that the soldered joint be protected by paint or varnish.

Soldering Aluminum. See Aluminum Soldering.

Soldering, Electric. See Electric Soldering.

Soldering Fluxes. In order to obtain a good joint by means of soldering, it is necessary that there be more than mere adhesion between the solder and the metal. There must be an alloy formed between the metal and the solder, and, in order that this alloy may be formed, the surface of the metal must be entirely free from foreign substances, such as oxides, oils, or various kinds of solid matter. This is accomplished by using a flux that melts at the fusing temperature of the solder and thus excludes the air. The flux used in any case depends somewhat upon the nature of the work. The fluxes generally used for soft soldering are resin, sal-ammoniac, and zinc chloride, although there are many others employed. For hard soldering or brazing, pulverized borax or boracic acid in powdered form are commonly used. Another flux that has given good results is made of equal parts, by weight, of borax and potash, this mixture being melted and, when cool, pulverized.

Soldering Paste: The requirements of electrical work are such that in some cases an acid soldering flux cannot be used, and it is common practice to use what is known as a *soldering paste.* For soldering copper wires and other electrical conductors, a paste is unequalled and is especially adapted for work in which spattering and corrosion are objectionable.

Solder, Silver. See Silver Solder.

Solenoid. A solenoid is a coil of wire commonly wound in the form of a helix which exhibits the powers of attraction and repulsion at each end usually associated with a magnet. It may or may not have an iron core. In some cases, where a core is used it moves as an armature to perform some simple mechanical function. Solenoids are used for the operation of both direct-current and alternating-current equipment.

Solenoid Brake. One type of solenoid brake adapted for mill, crane and hoist motors and similar classes of service, is so arranged that the brake mechanism is held in the off or release position by a coil and plunger. The action is as follows: When power is applied to the motor the coil is energized and, consequently, the brake is released; when the power is shut off a spring-setting device forces the mechanism into the closed or braking position. Either a direct-current series solenoid or an

alternating-current shunt solenoid can be mounted on the brake mechanism, these solenoids being interchangeable to permit operation either with alternating or direct current.

Solid. In physics, the term solid is used to designate a substance in which the attractive force between the molecules is so strong that the form of the substance cannot be easily changed. Popularly defined, a solid substance is, therefore, one that has a definite form and a definite volume.

In mathematics, a solid is a body having three dimensions such as height, width, and length; the term "solid" is used in distinction to *surface*, which is a mathematical quantity which has width and length, but no height or thickness.

Soluble Oils for Cutting Tools. The soda water mixtures which formerly were used so extensively on metal-cutting tools to avoid some of the objections to the use of plain water, were at first mixtures of sal-soda and soft soap, combined with water in various proportions, the soft soap being added to give the required body to the mixture rather than for its lubricating qualities. As machine speeds increased, it was discovered that lubrication was required as well as cooling service, so it has become quite general practice to add some lard oil to the soda water. The addition of lard oil improved the lubricating capacity of the soda water cutting lubricants, but there are objections to its use on account of the free fatty acid developed, particularly in the presence of heat; the deterioration if used repeatedly as a cutting lubricant; the high cost; and the loss in the cooling capacity after repeated use. Soda water has little more lubricating value than has plain water; hence, the lubricating qualities of various other oils would be as efficacious if the oils were simply emulsified with water. In fact, better results are obtained by compounding various oils which blend (that is, form stable emulsions) immediately with cold water. These soluble cutting oils are used extensively for machining operations requiring flooded lubrication of cutting tools.

Sorbite. Sorbite is a constituent obtained in steel when drawing the temper of hardened steel to a temperature somewhere between 400 and 800 degrees C. (750 and 1470 degrees F.). It reaches its maximum at 600 degrees C. (1110 degrees F.) See also Steels.

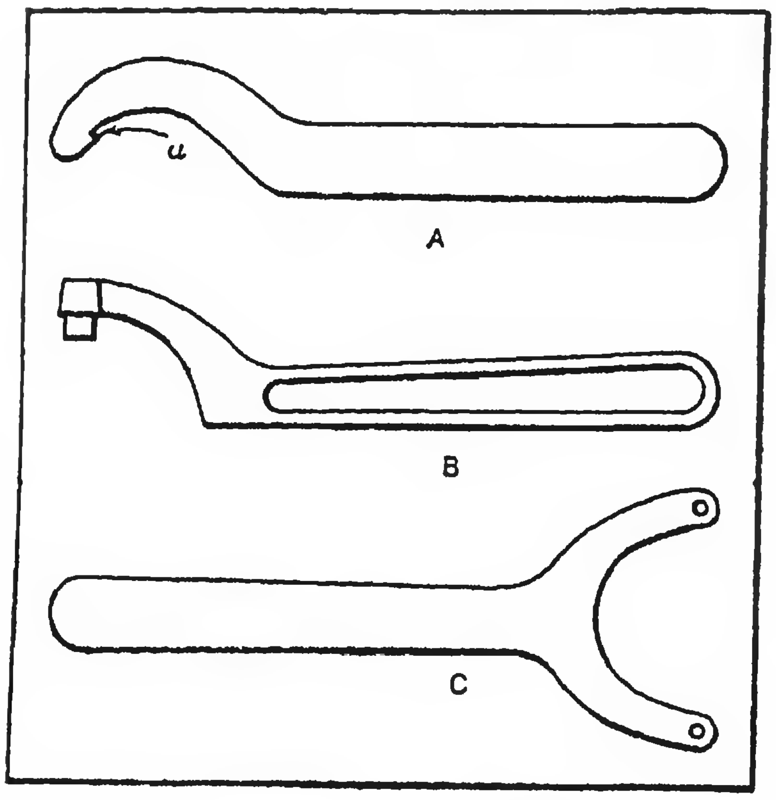
Spacing Tables. In order to avoid laying out rivet holes in plates prior to punching, spacing mechanisms are often used in conjunction with punching machines. The plate or other part to be punched is carried by a table that is shifted an amount equal to the spacing required between the holes. This spacing table may have either a hand or automatic feed. The mechanism of an

automatic spacing table is so designed that the table is shifted as soon as the punch has moved up far enough to clear the work, the movement being completed before the punch again engages the stock. For girder work, where the rivet spacing may vary in each row, the problem of spacing is more difficult than in the case of boiler work, where the spacing is uniform on each seam. Mechanical spacing devices for girder work may be partly automatic so that the machine continues a given spacing until it is changed by the operator or the machine may follow a templet previously set for the required spacing and be entirely automatic.

Span. This is an old length measure, equal to 9 inches.

Spandrel. A spandrel (or fillet) is a plane figure or surface enclosed between a circular arc, equal to one-fourth of the complete circle, and two tangents to the circle at the extreme ends of the arc. If the radius of the circular arc equals r, then the area of the spandrel equals $0.215\ r^2$.

Spanner Wrenches. Cylindrical nuts are occasionally provided with shoulders or milled slots for purposes of adjustment, and, in cases of this kind, a hook-type spanner wrench, such as that shown at *A*, is needed. The portion *a* is so made that it will enter any one of the slots and serve as a means for tightening the nuts. The single pin-type of wrench, *B*, is used for the same kind of work as style *A;* radially drilled holes around the periphery of the nut are provided, so that the pin will enter any one of these holes. There are many cases when a cylindrical nut is set into some portion of a machine in such a way that there is no protruding portion to which a wrench of the ordinary type can be applied. In cases of this kind, several holes may be drilled in the face of the nut so that the pins in the wrench shown at *C* can be used to give the necessary grip, when adjustment is needed.



Spanner Wrenches

Spark-Arc. See Electrical Discharge Machining.

Spark-Plug Screw Threads. The S.A.E. Standard includes the following sizes: ⅞-inch nominal diameter with 18 threads per inch; 18-millimeter nominal diameter with a 1.5-millimeter

pitch; 14-millimeter nominal diameter with a 1.25-millimeter pitch; 10-millimeter nominal diameter with a 1.0 millimeter pitch; ⅜-inch nominal diameter with 24 threads per inch; and ¼-inch nominal diameter with 32 threads per inch. During manufacture, in order to keep the wear on the threading tools within permissible limits, the threads in the spark plug GO (ring) gage should be truncated to the maximum minor diameter of the spark plug; and in the tapped hole GO (plug) gage to the minimum major diameter of the tapped hole.

Spark Tests for Steel. It has long been the practice of toolmakers and hardeners to judge the grade of steel by observing the characteristics of the spark produced when a sample is held against an abrasive wheel. It is doubtful if anyone could estimate within plus or minus 0.10 per cent of carbon, unless the grinding wheel speed and the type and grade of wheel have been standardized, and unless analyzed steel standards from the same heat as the steel being tested are available. But if wheel speed and wheel are standardized and a standard from the same heat is available, then it is possible to estimate the carbon content to within plus or minus 0.02 per cent for the lower carbon steels, and to within plus or minus 0.05 per cent for the higher carbon steels.

The carbon content of alloy steel may be determined as accurately as for the straight carbon steels, provided the percentage of alloying elements is not very high, as would be the case, for instance, in high-speed steel. In addition, the presence of other elements may be determined. The presence of chromium can readily be determined within ranges of 0.3 per cent; nickel below 1.5 per cent is somewhat difficult to determine, but nickel from 1.5 to 3.5 per cent is readily discerned. In tungsten steel, one may discover minute traces of tungsten, and also distinguish between 2 per cent, 5 per cent, and 8 per cent tungsten steel and higher. The beginner should become accustomed to the carbon steels first, for after he has become thoroughly conversant with these, the examination of other steels will be easier.

Spark Pictures: In looking at the spark picture produced by carbon steel, when pressed against an abrasive wheel, a series of streaks and explosions are in evidence. By observing at first, steels of known composition, and perhaps keeping samples as standards for comparison, other steels may be classified in a general way by the spark test. The piece of steel to be tested should not be placed against the edge of the wheel. It has been found more satisfactory to place it against the side surface of the wheel at a point ¼ to ½ inch from the outer periphery. There should be no obstruction in front of the spark, as it is generally easier to study the characteristics at a distance from the wheel at a

point where the carrier lines are more separated. A black background should be used, against which the sparks can be clearly seen. The best way is to set the wheel in a black painted cabinet, so that the color and characteristics can be readily seen. The length of the spark has little to do with the determination of the grade of steel, because the length usually depends on the size of the piece being tested and the method of pressing it against the wheel. The only difference in the method of testing hardened and annealed work is that more pressure is required to obtain the same length of spark with an annealed piece of work.

Spatter-Ex. A metal coating to obviate the grinding or chipping of weld spatter from the metal surrounding a weld. The transparent jelly-like coating prevents the adhesion of spatter. After the welding operations have been completed, any spatter on the surrounding surfaces is merely brushed off. The compound is especially applicable to arc, flash, or butt-welding operations.

Spauldite. Material manufactured from tightly woven fabric thoroughly impregnated with a phenolic binder. The saturated fabric sheets are forced under heavy pressure and intense heat into a dense homogeneous mass. Suitable for gears. Gears as small as ¼ inch pitch diameter, for transmitting 0.06 horsepower per inch of face at a speed of 100 feet per minute, and gears as large as 60 inches pitch diameter, for transmitting 58 horsepower per inch of face at a speed of 3000 feet per minute, have been made from this material.

Specific Gravity. In the case of solid bodies, specific gravity is a number indicating how many times a certain volume of a material is heavier than an equal volume of water. As the density of water differs slightly at different temperatures, it is the usual custom to make comparisons on the basis of water at a temperature of 62 degrees F. The weight of one cubic inch of pure water at 62 degrees F. is 0.0361 pound. If the specific gravity of any material is known, the weight of a cubic inch of the material can, therefore, be found by multiplying its specific gravity by 0.0361. To find the weight per cubic foot of a material, the specific gravity of which is known, multiply the specific gravity by 62.355. If the weight of a cubic inch of a material is known, the specific gravity is found by dividing the weight per cubic inch by 0.0361. If the weight per cubic foot of a material is known, the specific gravity is found by multiplying this weight by 0.01604. The *specific gravity of liquids* is the number which indicates how much a certain volume of the liquid weighs compared with an equal volume of water, the same as in the case of solid bodies. The specific gravity for liquids heavier than water equals $145 \div (145 - \text{degrees Baume})$. For liquids lighter than water,

the specific gravity equals 140 ÷ (130 + degrees Baume). The *specific gravity of gases* is the number which indicates their weight in comparison with that of an equal volume of air. The specific gravity of air is 1, and the comparison is made at 32 degrees F.

Specific Gravity Measurement. See Hydrometer.

Specific Heat The specific heat of a given substance is the ratio of the heat required to raise the temperature of a certain weight of the substance one degree F. to that required to raise the temperature of the same weight of water one degree. As the specific heat is not constant at all temperatures, it is generally assumed that it is determined by raising the temperature from 62 to 63 degrees F. For most substances, however, it is practically constant for temperatures up to 212 degrees F. Considerable difficulty has been experienced in determining the specific heat accurately. In the case of solid bodies and liquids, methods have been developed by means of which the specific heat has been determined to within an accuracy of probably 0.5 per cent, but in the case of gases, the specific heats are less accurate, as evidenced by the fact that different investigators give somewhat different values. The fact that slight impurities in solids, liquids, and gases affect the specific heat must also be taken into consideration. Hence, the figures given in any table of specific heat may be expected to vary slightly from figures given in other tabulations.

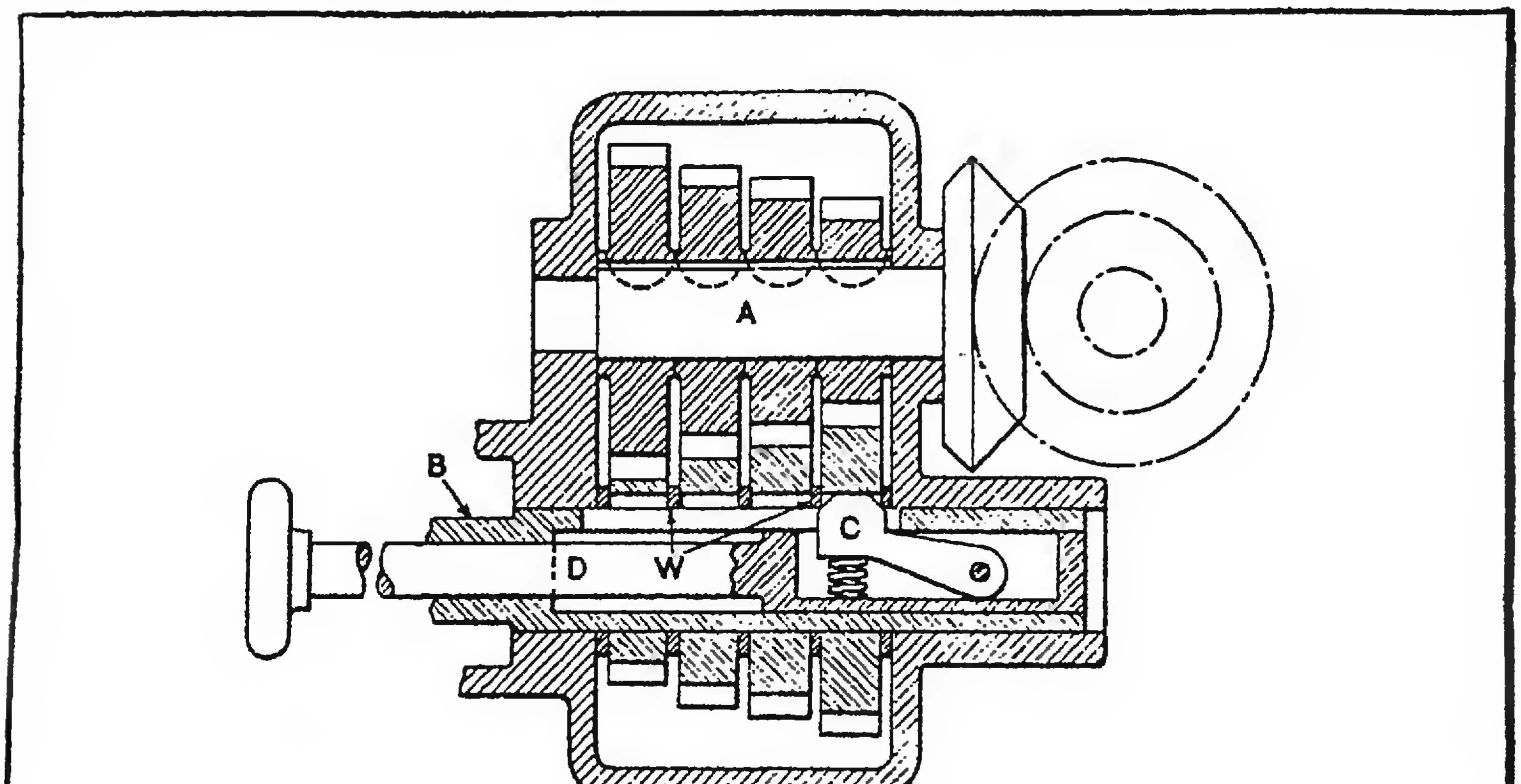
Specific Heat of Air: The specific heat of air, or the heat units required to raise the temperature of one pound of air one degree Fahrenheit, equals, at constant pressure, 0.2375 B.T.U. (British Thermal Units), and at constant volume, 0.1689 B.T.U.

Speed-Changing Mechanisms. When speed variations are essential to the operation of machines such, for example, as are used for some kinds of manufacturing work, the changes are usually obtained by hand-controlled speed-changing devices. If such variations are seldom required, it may be necessary to stop the machine and make an adjustment, or replace one or more gears with others of different diameters. When changes of speed are frequently needed, the machine is generally equipped with some mechanical device enabling one or more variations to be obtained rapidly, by simply moving a wheel, lever, or rod which controls the combination or velocity ratio of the mechanism through which the motion is transmitted. If the machine is of the automatic type, the speed may be regulated according to varying conditions, by the mechanism of the machine itself, which is constructed or adjusted beforehand to give the proper changes. The exact arrangement of the details depends, in any case, upon

conditions such as the speed variation required, the importance of rapid changes, the relation of the speed-controlling mechanism to other parts of the machine, etc.

Mechanical devices for varying the speed are of special importance on machine tools. In fact, most machine tools are so constructed that the speed of the cutting tool or of the part being operated upon can be varied, the range or extent of the variation depending upon the type of machine. These changes are desirable in order to cut different kinds of metal at the most efficient speed. Another important reason for speed variation is to secure the proper surface speed for revolving parts, regardless of the diameter, and the correct cutting speeds for rotating tools of different sizes.

Types of Speed-changing Mechanisms: When a variation of speed is obtained by changing the velocity ratio of two or more parts forming a train of mechanism, one of the following methods is generally employed: (1) By means of conical pulleys connected by a belt or cone-pulleys having "steps" of different diameters upon which a connecting belt may be shifted; (2) by the use of cone-pulleys in conjunction with one or more sets of gears; (3) by means of toothed gears exclusively, with an arrangement that enables the motion to be transmitted through different ratios or combinations of gearing; (4) by employing a friction transmission consisting of driving and driven disks, pulleys, or wheels, so arranged that one member (or an intermediate connecting device) can be shifted relative to the axis of the other for varying the speed. These different types or classes of speed-changing mechanisms are constructed in various ways.



Double Cone of Gears with "Diving Key" which Controls Speed Changes

When toothed gearing is used exclusively in a speed-changing mechanism, the most common arrangements may be defined as the sliding-gear type; the clutch-controlled type; the gear-cone and sliding-key type; the gear-cone and expanding-clutch type; the gear-cone and tumbler-gear type; and the multiple crown-gear and shifting-pinion type.

Double Gear Cone Transmission: Speed changes for many types of machine tools and other classes of machinery, are obtained by some form of geared transmission. The speed ratio between the driving and driven shaft usually is obtained either (1) by shifting gears to bring different combinations into mesh; (2) by shifting clutches which cause the motion to be transmitted through different combinations; (3) by using a double gear cone and a shifting key as shown by the illustration. This latter method is often employed (in connection with the feeding mechanisms of machine tools, etc.). One cone of gears (the number of which is varied according to requirements) is attached to the driving shaft *A*, whereas the gears of the other mating cone are free to rotate upon the shaft *B*, except when locked to it by a "diving key" or plunger *C* which can be moved from one gear to another by means of a rod *D* that is shifted in some suitable way. This rod may simply have a knob on the end, as indicated in the illustration, so that it can be pulled out or pushed in, or it may be attached to a hand-lever to facilitate moving it. When the diving key is in the position shown in the illustration, the mechanism will give the slowest speed, since the largest gear of the driven cone is clutched to the shaft *B*. Obviously, each individual gear of the lower cone may be successively locked to the driven shaft by pulling rod *D* and key *C* forward. As the illustration indicates, the key is pivoted at one end, and, as it is shifted from one gear to another, the beveled edges engage the wards *W*., which cause the key to move radially inward out of engagement with one gear before engaging the next. These wards are simply washers placed between the different gears, and they cause the key to be entirely disengaged from one gear before engaging the next successive one in the cone; moreover, the operation of changing from one speed to another is facilitated by these wards, inasmuch as the pressure required to disengage the key radially is somewhat less than would be necessary if the key were simply moved longitudinally.

Speed Variations and Gear Ratios: Proportioning a train of gears to obtain a given velocity ratio, or possibly a given series of speeds, is frequently encountered in the design of geared transmissions. When the problem is simply that of obtaining a given velocity ratio, and when the latter is so large that more than one pair of gears should be used, a uniform reduction between the

different pairs is conducive to the highest efficiency. Whenever this arrangement is practicable, the ratio of each pair in a train may be determined by extracting the root of the total ratio. If there are two pairs of gears, extract the square root; for three pairs, extract the cube root, etc. For example, if the total ratio between the first driving and the last driven gear is to be 125 to 1 and three pairs of gears are to be used, the ratio of each pair should preferably equal 5 to 1, since $\sqrt[3]{125} = 5$.

In designing gear combinations for varying spindle speeds or feeding movements, it is general practice, among machine tool builders particularly, to vary the speeds in geometrical progression, successive speeds being obtained by multiplying each preceding term by a ratio or constant multiplier. Thus, if the slowest speed is 50 revolutions per minute and the ratio is 1.3, the succeeding speeds will equal $50 \times 1.3 = 65$; $65 \times 1.3 = 84.5$; $84.5 \times 1.3 = 109.8$.

When the fastest speed F and the slowest speed S in a series are known and also the total number of speeds N, the ratio may be determined by the well-known formula:

$$\text{Ratio} = \sqrt[N-1]{\frac{F}{S}}$$

Since logarithms would ordinarily be used for the extraction of this root, the ratio may be obtained as follows:

Rule: Subtract the logarithm of the slowest speed from the logarithm of the fastest speed and divide the difference by the total number of speeds minus 1; the result will equal the logarithm of the ratio.

In actual practice, the exact progression obtained may be modified slightly to permit using gears of a certain diametral pitch. For machine tool transmissions, the speed ratio should, as a general rule, be between 1.3 and 1.5, as otherwise there will be either too small or too great a difference between successive speeds. There would be no practical advantage in a series of speeds varying by small increments equivalent to a ratio of say, 1.1, whereas, if the ratio were 1.7 or possibly 2, the changes from one speed to the next would be excessive. Feeding mechanisms may be designed for ratios of 1.2 or less, depending on the type of machine.

Speeds of machine tool drives and especially feed changes are sometimes varied according to "chromatic scale progression," with a ratio of either 1.4142 or 1.189 in case a lower ratio is required. The first ratio is the square root of 2, and the second the fourth root of 2. The object of using these particular ratios is to obtain a series of speeds or feeds containing the even ratios, 2, 4, 8, 16, etc.

Speed, Critical. See Critical Speed.

Speed Indicators. The simplest instruments for determining the speeds of shafts, etc., are commonly called *speed indicators* or *revolution counters.* A typical form of speed indicator has a spindle that is held into engagement with the center of a revolving shaft, thus transmitting rotary motion to a dial or pointer. Each revolution of this pointer or dial, which turns much slower than the shaft, is equivalent to a certain number of revolutions of the shaft. For instance, one turn of a pointer may represent 100 revolutions, and the number of revolutions for any fractional part of a turn is indicated by suitable graduations. To obtain the speed in revolutions per minute, this instrument is used in conjunction with a watch. Another form of speed counter is so arranged that the revolutions made during a given time are indicated by figures which change automatically. For instance, if the reading is 500 at the instance the spindle of the instrument is pressed against the shaft and 700 one minute afterward, the difference between the first and second readings, or 200, indicates the speed in revolutions per minute. If considered desirable, the register may be set to zero by holding the point of the spindle against the revolving shaft for a short time. A more highly developed instrument known as a *tachoscope* consists of a revolution counter and a non-magnetic precision stop-watch which are so connected that they operate simultaneously the moment a slight pressure is applied to the spindle which engages the revolving shaft. As soon as the pressure is released, both the revolution counter and the watch stop at the same time, thus indicating on the dials the number of revolutions made and also the time elapsed. See also Tachometer.

Speed Lathe. The name "speed lathe" is usually applied to light lathes which have neither back-gears nor a tool carriage, and are intended for rotating parts rapidly either for polishing, hand turning, or filing. When turning parts by hand-manipulated tools, the ends of the tools are supported by a T-shaped rest that is clamped to the bed. Lathes of this class are sometimes known as "hand lathes." Many lathes of the "speed" class have either a lever or a combination lever-and-screw feeding motion for the tailstock spindle, the lever being very convenient for feeding drills or reamers which are held in the end of the spindle. The term "speed lathe" is also applied by some manufacturers to a design which has a hand-operated carriage, and one that is without back-gears or a power feeding mechanism.

Speed Range, Chromatic. See Chromatic Speed Range.

Speed Reducers. A speed reducer for obtaining a reduction of speed between driving and driven shafts consists of a combination of gearing enclosed in a housing to form a self-contained unit. The housing serves to protect the gearing from dust, etc., and to retain lubrication. It also acts as a safeguard by enclosing the gears. Speed reducers may be classified according to the type of gearing. For example, some speed reducers have spur gears, others herringbone gears, and a third class, worm gearing. The reduction ratios cover a wide range and may vary from 1½ or 2 to 1, up to 5000 to 1 or higher in single units. If these units, however, are combined so that the driven shaft of one unit connects with the driving shaft of another, ratios that are much higher than ever required in practical work may be obtained readily. See also Speed-changing Mechanisms.

Speed-Variator of Electric Type. The General Electric speed-variator unit operates from an alternating-current line and provides a wide range of speeds by means of the well-known generator-voltage-control arrangement. This equipment is adapted for driving machine tools, pumps, textile and paper machinery, etc., and is applicable to all kinds of material-handling operations. Each unit consists of an adjustable-speed, direct-current motor; an adjustable-voltage motor-generator set with control; and a separately mounted generator-field rheostat. Standard speed ranges are available in ratios up to 16 to 1. The motor can be mounted directly on the driven machine, with the speed-changing control located nearby. The units are designed to operate from three-phase, 60-cycle, 220-, 440-, and 550-volt alternating-current power. The potentiometer type of generator-field rheostat provides speed changes varying by small increments over a wide range.

Spellerizing. A process known as "spellerizing" has been developed to increase the life of pipe steel. By this process, the steel is treated mechanically and it consists in first subjecting the skelp, at a proper temperature, to the action of rolls having regularly-shaped projections on their working surface. The skelp is then subjected to the action of smooth-faced rolls, and by repeating these rolling operations, the surface of the metal is worked so as to produce a uniformly dense texture which is better adapted to resist corrosion, especially in the form of pitting.

Spelter and Spelter Solder. Spelter is a name which, in the past, was frequently used for zinc, but which, at the present time, is used only commercially, and then only when it refers to zinc cast in ingots. Spelter solder, an alloy of copper and zinc, used in hard soldering or brazing, is also frequently spoken of simply

as "spelter," but in that case the expression is an abbreviation of the term "spelter solder."

Spherical Candle Power. The spherical candle power, or "mean spherical candle power," of a lamp, is the average candle power of the lamp in all directions.

Spheroid. A spheroid or an *ellipsoid of revolution* is formed by an ellipse rotating about one of its axes, thereby forming a solid of revolution. A spheroid may also be defined as an ellipsoid in which two axes are equal.

Spheroidizing. According to the S. A. E. definition, spheroidizing is the prolonged heating of iron-base alloys at a temperature near, but generally slightly below, the critical temperature range followed usually by relatively slow cooling. In the case of small objects of high-carbon steels, the spheroidizing result is obtained more rapidly by prolonged heating to temperatures alternately within and slightly below the critical temperature range. The object of this heat-treatment is to produce a globular condition of the carbide.

Spiegeleisen. This is an alloy of iron and manganese used in both Bessemer and open-hearth steel-making practice. The term is applied commercially to alloys containing up to about 30 per cent manganese. In Bessemer steel practice, molten spiegeleisen is added to the steel after the blow, for recarburizing and obtaining the desired manganese content. Spiegeleisen also is frequently used with scrap and pig iron in the open-hearth charge in order to raise the manganese content and aid in cleansing the bath. The term "spiegeleisen" means "mirror iron," this name being given to the alloy on account of the brilliancy of its fracture.

Spindle. In general, a spindle is a cylindrical machine part, generally capable of being rotated and, usually, the main or most important shaft in a machine. A lathe spindle, for example, is the shaft mounted in the headstock bearings, in the end of which the live center is held and from which the work in the lathe is driven.

Spindle, Standard Milling Machine. See Milling Machine, Standard Spindle.

Spinning Metals. This operation is sometimes performed on an engine lathe, although more often on a lathe designed specially for the purpose. It consists of forming a disc of sheet metal into a hollow form. A special chuck is made of steel or hardwood to the exact size and shape of the part to be formed. A disc of sheet metal is placed against the end of the chuck

and held by a ball-bearing disc supported in the tailstock. Considerable pressure must be applied to keep the work from flying out. The chuck is revolved at high speed and a long-handled tool with a smooth, rounded head is manipulated by the operator against the flat face of the work. By applying pressure with the tool, he is able to force the metal to conform to the shape of the chuck.

Spiral and Helix. A spiral may be defined mathematically as a curve having a constantly increasing radius of curvature. Spirals are often confused with helices, as for instance, when speaking of "spiral" gears or "spiral-riveted" pipe, which should properly be termed "helical" gears and "helical-riveted" pipe. Both the spiral and the helix are exemplified in spring design, the spiral being represented by a watch spring, while the helix is represented by a coil spring.

Spiral Bevel Gears. Spiral type bevel gears have been used widely in automobile rear axle drives in preference to bevel gearing having straight teeth. There has also been an increasing demand for this type of gearing for other purposes. The spiral design operates more smoothly than bevel gears with straight teeth and has certain other advantages. The relation between spiral and straight tooth bevel gearing is practically the same as the relation between ordinary spur gears and helical gears applied to parallel shafts. The teeth of spiral bevel gears are not a true spiral, although the actual curve, when developed on a plane, closely approximates the spiral curve. Gears of this kind are cut on machines of the generating type.

Spiral Bevel Gear Capacity: Spiral bevel gears have a load-carrying capacity that is somewhat greater than that of straight-tooth bevel gears of similar proportions. The difference in capacity, however, is not very great, and the formula for straight-tooth gears may also be applied to the spiral bevel type. One of the principal reasons why spiral bevel gears are slightly superior to the straight-tooth form as power transmitters is that there are more teeth in contact and the load on any one tooth is less. Another reason is that the load is never concentrated on the point of a tooth throughout its whole length. When there is contact at the point at one end, the contact is toward the flank at the other end, and the average height from the root, at which the load is applied, is much less than the total height of the tooth. The smoothness of operation is another favorable factor tending toward greater load capacity, as in the case of herringbone or double-helical gearing for connecting parallel shafts.

The tooth of a spiral bevel gear has to take both the transmitted load and the thrust load. This total load equals the trans-

mitted load divided by the cosine of the spiral angle. For a 30-degree spiral angle, the total load is about 1.15 times the transmitted load. This additional tooth load on a spiral bevel gear tooth, as compared with a straight tooth, is more than offset by the increased number of teeth in contact. While the tooth thickness of the spiral bevel gear is less than that of the straight gear, the length of the curved tooth is correspondingly greater, so that the sectional area on the pitch cone surface is practically the same for the straight and spiral forms of teeth of corresponding pitch.

Spiral Gearing. Gears which have a pitch surface cylindrical in shape, and in which the axes of the teeth are not straight lines, as in spur gearing, but form a helix on the surface of the pitch cylinder, are often called *spiral* gears. The terms "spiral" gear and "helical" gear are synonymous in usage, but the former of these terms is theoretically incorrect. See Helical Gears.

Spiral Head. A spiral head is an attachment for milling machines, used for indexing or dividing and also in connection with helical milling. See Indexing Attachments.

Spiral-Jaw Clutch. A spiral-jaw clutch is a positive clutch in which the tops of the tooth surfaces are helicoidal, the front of the tooth being flat and in the plane of the axis of the clutch. Clutches of this type can only transmit motion in one direction, and are, therefore, known as right- and left-hand.

Splicing Rope. See Rope Splicing.

Splines and Serrations. A splined shaft is one having a series of parallel keys formed integral with the shaft and mating with corresponding grooves cut in a hub or fitting; this is in contrast to a shaft having a series of keys or feathers fitted into slots cut into the shaft. This latter construction weakens the shaft to a considerable degree because of the slots cut into it and, as a consequence, reduces its torque-transmitting capacity.

Splined shafts are most generally used in three types of applications: (1) for coupling shafts when relatively heavy torques are to be transmitted without slippage; (2) for transmitting power to slidably-mounted or permanently-fixed gears, pulleys, and other rotating members; and (3) for attaching parts that may require removal for indexing or change in angular position.

Splines having straight-sided teeth have been used in many applications; however, the use of splines with teeth of involute profile has steadily increased since (1) involute spline couplings have greater torque-transmitting capacity than any other type; (2) they can be produced by the same techniques and equip-

ment as are used to cut gears; and (3) they have a self-centering action under load even when there is backlash between mating members.

American Standard Involute Splines: These splines or multiple keys are similar in form to internal and external involute gears having a pressure angle of 30 degrees. The method of pitch designation is such that the numerator or diametral pitch determines the circular pitch and the basic width or tooth thickness and the denominator or stub pitch determines the addendum and dedendum. The general practice is to form the external splines either by hobbing, rolling, or on a gear shaper, and internal splines either by broaching or on a gear shaper. The internal spline is held to basic dimensions and the external spline is varied to control the fit. Involute splines have maximum strength at the base, they can be accurately spaced and are self-centering, thus equalizing the bearing and stresses, and they can be measured and fitted accurately.

American Standard Involute Serrations: American Standard involute serrations are involute splines with a 45-degree pressure angle. They are principally used for close fits which are not subject to sliding. Other classes of fits may be employed but are not covered in this standard. Compared with involute splines, serration teeth are shallower, have broader bases and less radial depth of contact, and sometimes offer manufacturing advantages. Contact pressures, sliding resistances, and radial forces are greater under the same load. The method of pitch designation is the same with the numerator or diametral pitch determining the circular pitch and basic space width or tooth thickness and the denominator or stub pitch determining the addendum and dedendum. Fine pitches are frequently used, resulting in high numbers of teeth and a wide range of index positions. A range of from 6 to 100 teeth is provided for 10/20, 16/32, and 24/28 pitches and a more limited range of teeth for 32/64, 40/80, 48/96, 64/128, 80/160 and 128/256 pitches.

Splines, Rolled. See Gears, Rolled.

Split-Pole Converter. See Regulating Pole Converter.

Sponginess. Sponginess in castings is due to the formation of gas bubbles in iron at the instant of solidification. In all ordinary cases, this is due to an improper mixture of iron. However, if the casting is very thick at one place, but otherwise thin, it will be impossible to obtain a mixture which will have satisfactory properties for general work and not be spongy at the points of extraordinary thickness.

Spontaneous Combustion. Spontaneous combustion or spontaneous ignition is a condition whereby a material ignites without having its temperature increased by applying heat from an external source. Coal, when stored in large quantities, is likely to ignite in this manner. Other substances that, under the right conditions, have been known to generate sufficient heat to cause spontaneous ignition are coke, lampblack, sawdust, charcoal, oily rags, cotton, flax, hemp, wool, oils, metallic powders, and dust of various kinds. Boiled linseed oil is the most dangerous of oils commonly used in industrial plants. Animal oils have but slight tendency toward spontaneous ignition, as compared with some of the vegetable oils which readily combine with the oxygen of the air. Mineral oils are not considered dangerous in this respect. The spontaneous ignition of oil-soaked rags or waste which has been left in a warm room or in the sun is among the more common occurrences of this kind. In this case ignition is caused by the rapid oxidation of the oil spread out over the large surface afforded by the threads in the waste or the folds of the cloth. As the result of this rapid oxidation, the temperature finally rises high enough to cause ignition.

Spot Facing. This term is generally applied to the operation of truing a comparatively small surface or spot, as, for example, when a true seat is formed on a casting or forging for the under side of a screw head. The spot that is faced true may be a circular raised pad on a casting or merely the surface around a bolt hole. Spot facing for screw heads may be done with a counterbore or counterboring tool, which then is used merely to remove enough metal to form a true seat. If this same type of tool is used to enlarge a hole, as, for example, when the enlarged part is to receive the fillister head of a machine screw, then the operation becomes counterboring.

Back Spotfacer: When a hole extends through some part of a casting or forging so that the surface around the inner end cannot be spotfaced in the usual manner, a back spotfacer is used, assuming that such inner surfaces require truing. A back spotfacer consists of a shank or driving bar which is inserted in the machine spindle, and a removable facing cutter or spotfacer which is inserted on the end of a shank after the latter is advanced through the hole far enough to receive the cutter on the projecting end. One commercial type of back spotfacer has a projecting driving pin in the cutter which engages a groove and pocket of the driving bar. This groove is of the bayonet lock type, thus permitting the cutter to be attached to or removed from the bar readily. Back spotfacing cutters may be either of the single or double type. The double type has cutting teeth on

both sides so that opposed inner surfaces may be trued quickly. These spotfacing cutters are also made for either right-hand or left-hand cutting.

Spot Welding. Spot welding works on the principle that when a large amount of electric current is passed between two metal sheets, held tightly together between two welding electrodes of rather small diameter (usually less than half an inch), the resistance to the flow of current will develop enough heat to cause fusion of the metal at the spot under the electrodes.

Streamlined stainless steel railroad cars are put together almost entirely by spot welding in such a manner that it is almost impossible to detect the spots. The work is done at high speed—in a fraction of a second per spot. If the weld were made slowly, the weld would be of poor quality.

Spot welding of aluminum is common practice in fabricating the wings and fuselages of aircraft. It requires a tremendous amount of current (about 30,000 amperes) which must pass between the electrodes and through the work in a few thousandths of a second. Spot welding of steel requires much less current and is relatively easy to perform.

Springback Allowance. An allowance must be made when various springy metals are bent as there is a tendency for them to spring back a certain amount upon removal of the bending force. For example, it may be necessary to bend a piece of metal to an angle of 75 degrees in order to obtain a 60-degree bend.

Spring Brass and Bronze. Brass and bronze compositions are used for both coiled and flat springs especially where resistance to corrosion is essential.

Brass Wire—S.A.E. Standard No. 80: This wire is used for making springs. Grade A is intended for severe service, and Grade B for ordinary conditions.

Composition: Copper, (Grade A) 70 to 74, (Grade B) 64 to 68; lead, max., (Grades A and B) 0.10; iron, max., (Grade A) 0.06, (Grade B) 0.07 per cent; zinc, (Grades A and B) remainder.

Physical Properties: This wire shall have a tensile strength of at least 100,000 pounds per square inch, and it should be capable of being bent through an angle of 180 degrees around a wire of the same diameter without breaking.

Phosphor Bronze Wire—S.A.E. Standard No. 81: This wire is intended primarily for springs.

Composition: Tin, 4 to 6; phosphorus, 0.03 to 0.40; zinc, max., 0.20; iron, max., 0.10; lead, max., 0.10 per cent; copper, remainder.

Physical Properties: Minimum tensile strength varies from 100,000 to 130,000 pounds per square inch, depending upon the

diameter, the strength in pounds per square inch decreasing as the diameter increases. This wire should withstand any bend through an angle of 180 degrees flat back on itself without fracture on the outside of the bent portion.

Phosphor-Bronze Strips—S.A.E. Standard No. 77: This specification covers bronze strip up to 0.080 inch thick and includes different tempers in two grades designated as A and B. The tempers are: Half Hard (2); Hard (4); Extra Hard (6); Spring (8). The numbers following the temper designations indicate the reductions during rolling in B. & S. gage numbers. These phosphor bronze strips are used for various kinds of springs. Grade A spring temper is generally used for flat springs formed with easy bends across the grain. Grade B, extra hard temper, is usually employed for flat spring with easy bends either across or with the grain. Grade B, hard temper, is generally used for clips or contact springs with difficult bends. Grade A is also used for friction plates and clutches, and for thrust washers.

Composition: Tin, (Grade A) 4 to 6, (Grade B) 7 to 9; phosphorus, (Grade A) 0.03 to 0.40, (Grade B) 0.03 to 0.20; zinc, max., (Grades A and B) 0.20; iron, max., (Grades A and B) 0.10; lead, max., (Grades A and B) 0.10 per cent; copper, (Grades A and B) remainder.

Physical Properties: Minimum tensile strength, Grade A, half hard, 55,000; hard, 75,000; extra hard, 85,000; spring, 90,000 pounds per square inch, with elongation varying from 15 per cent for half hard to 1 per cent for spring temper. Grade B, half hard, 65,000; hard, 85,000; extra hard, 100,000 pounds per square inch, with elongation varying from 20 to 1 per cent for half hard to extra hard.

Spring Caliper. A spring caliper is a measuring tool used by machinists. The two legs of a spring caliper are joined by a spring (instead of a riveted joint) in such a manner that the bent ends are normally held apart, while a screw and nut are provided for forcing the measuring points together. Sometimes the nut is split so as to permit of rapid adjustment to an approximate dimension, after which the nut is closed and an accurate adjustment made by turning it on the screw.

Spring Cotter. A spring cotter, also known as split cotter and split pin, is a piece of wire bent double so as to form an eye at one end, and used for inserting in a hole drilled through a stud or shaft for retaining a nut or some other member. The wire is approximately semi-circular in cross-sections. When inserted in the hole, the outer ends of the cotter are spread apart to retain it in place. Strictly speaking, a spring cotter is a cotter made from spring steel wire, so that when it is bent over on itself

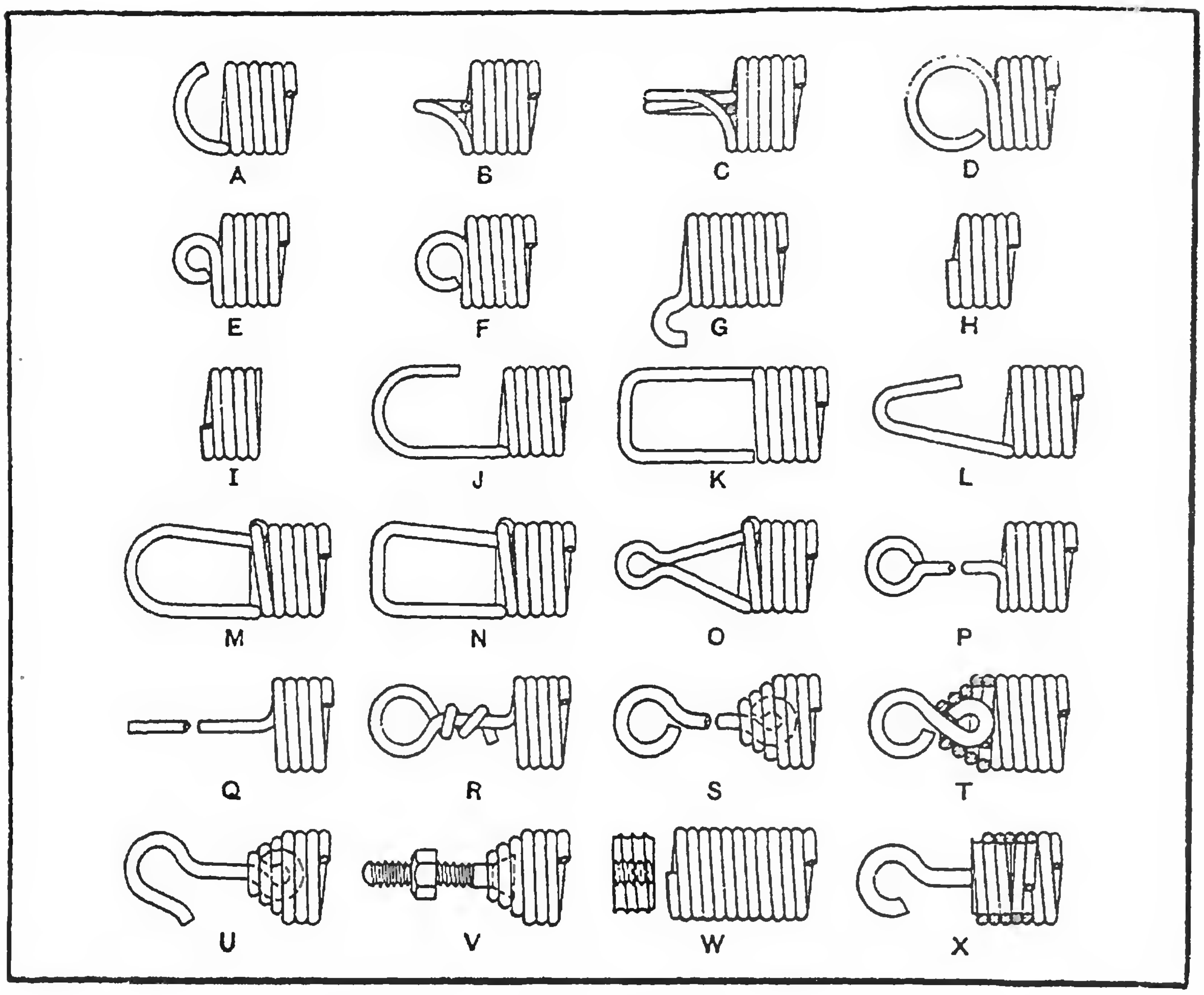


Fig. 1. Different Types of Spring Ends

it retains enough springing action at the ends, so that these tend to come apart and thereby bind or hold firmly in the hole into which the cotter is inserted.

Spring Ends. Extension springs are furnished with many different kinds of ends, some of which have become so commonly known in the trade that they are regarded as standard. The two hooks at opposite ends of a spring may be made in line and in the same or different planes; and they may be located at the center of the spring or on one side. A further variation may be obtained by arranging the ends out of line and they may even be located at right angles to each other. Some common forms of spring ends are shown by the two illustrations. Referring to Fig. 1, spring *A* has a regular machine hook over the center; *B*, a regular hand loop over the center; *C*, a double-coil hand loop over the center; *D*, a regular hand loop at the side; *E*, a small eye at one side; *F*, a small eye over the center; *G*, a small hook at one side; *H*, a plain end; *I*, a ground end; *J*, a long hook; *K*, a long square hook; *L*, a V-hook; *M*, a loop knotted or secured to the spring; *N*, a square loop knotted or secured to the spring; *O*, a knotted eye; *P*, an extended eye; *Q*, a straight end (usually annealed so that it can be twisted); *R*, an annealed end, eyed and twisted; *S*, a

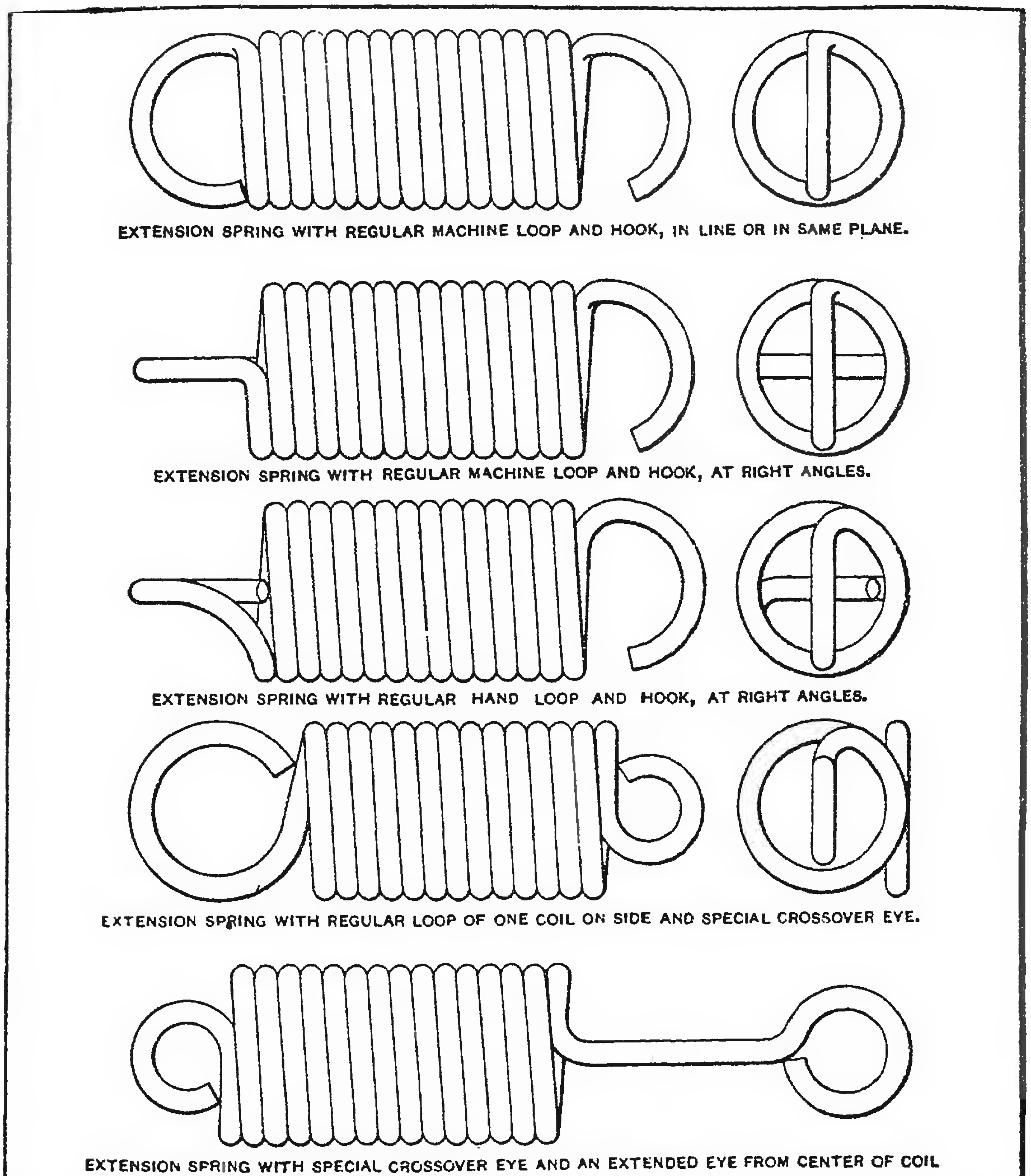


Fig. 2. Additional Examples of Spring Ends

tapered end with an extended swivel eye; *T*, a tapered end with a regular swivel eye; *U*, a tapered end with a swivel hook; *V*, a tapered end with a swivel bolt; *W*, a plain end with a plug to screw into place; and *X*, a plain end with a hooked plug.

Spring Materials. Different grades and types of steels and non-ferrous alloys are used for springs because of the different requirements, such as resistance to fatigue, corrosion, temperature, etc. While physical properties of different types of spring materials vary widely, there may also be decided variations in the same nominal grade or kind of material obtained from different

sources. The information which follows is intended as a general guide only.

Hard Drawn Spring Wire: This is a steel wire that is generally used for miscellaneous helical springs. It contains 0.50 to 0.65 carbon, 0.70 to 1.00 manganese, 0.10 to 0.20 silicon. In making this wire, hot-rolled open-hearth steel rods are annealed and then cold drawn, thus giving the wire its strength. The tensile strength for small diameters may vary from 200,000 to 300,000, and the elastic limit from 120,000 to 180,000 pounds per square inch.

Oil-Tempered Spring Wire: This steel wire is drawn to size from basic, open hearth rods after annealing. The composition is similar to hard drawn wire, excepting the carbon content which varies from 0.60 to 0.70 per cent. The strength is obtained by heat-treatment rather than by cold working.

Music Wire: This is a high-grade spring wire produced either in the electric furnace or by the acid open-hearth process, and it is extensively used for small springs subjected to high stresses. Music-wire gages range from 0.004 to 0.146 inch. The carbon content of music wire varies from 0.70 to 1.00, and manganese from 0.25 to 0.40 per cent. When the diameter is approximately 0.100 inch, the tensile strength is about 250,000 pounds per square inch. Music wire is more expensive than ordinary hard-drawn wire, but it can be subjected to higher stresses.

High-Carbon Annealed Wire: This type of wire is used extensively for valve springs and scale springs. It contains from 0.85 to 1.00 carbon, 0.30 to 0.45 manganese, and from 0.10 to 0.20 silicon. It is cold drawn from annealed rods made either by the electric or open-hearth processes. The springs are heat-treated after forming. The tensile strength, after heat-treatment, varies from 250,000 to 350,000, and the elastic limit from 150,000 to 250,000 pounds per square inch, depending upon the diameter.

High-Carbon Hot-Rolled Steel: This steel, which has a carbon content ranging from 0.90 to 1.05 per cent, is made either by the electric or open-hearth processes and is formed into springs while hot. This material is used for springs that are too large to coil cold and also for large leaf springs. The tensile strength varies from 175,000 to 195,000, and the elastic limit from 120,000 to 140,000 pounds per square inch.

Silicon-Manganese Steel: Steel of this kind is especially adapted to springs subjected to fatigue stresses. The ultimate strength ordinarily ranges from 200,000 to 250,000, and the elastic limit from 150,000 to 180,000 pounds per square inch. In the automotive industries, silicon-manganese steels are very generally used both for the coil and leaf springs. The S.A.E. silicon-manganese steel No. 9260 contains 0.55-0.65 carbon, 0.60-0.90

manganese, 1.80-2.20 silicon, 0.040 phosphorus (max.), and 0.050 sulphur (max.). It is a general practice to specify manganese on the high side of the range for leaf spring sections of 3/8 inch or over and the low or medium manganese content for sections under 3/8 inch. Silicon-manganese steel S.A.E. No. 9255 is like 9260, excepting the carbon range which is 0.50-0.60 per cent. The hardening temperature for these steels is 1500 to 1650 degrees F., and oil is the quenching medium.

Chromium-Vanadium Steel: This spring steel is superior to the straight carbon steel in toughness and when the operating temperature is too high for carbon steel. It contains from 0.45 to 0.55 carbon, 0.50 to 0.80 manganese, 0.90 to 1.20 chromium, 0.10 to 0.20 silicon, 0.15 to 0.20 vanadium. This steel is supplied either in the tempered or annealed condition. It is adapted to valve springs or wherever there are repeated stresses. The tensile strength varies from 200,000 to 300,000, and the elastic limit from 160,000 to 250,000 pounds per square inch.

Stainless Steel: This steel not only has high resistance to corrosion, but retains its strength in temperatures up to 700 degrees F., or even higher. For hard-drawn wire, the carbon content is 0.12, with chromium ranging from 17 to 20 and nickel 8 to 10 per cent. If supplied in the annealed condition for heat-treatment after coiling, the carbon content may vary from 0.30 to 0.40 per cent. The ultimate strength ranges from 150,000 to 280,000, and the elastic limit from 75,000 to 150,000 pounds per square inch.

Phosphor Bronze: A phosphor-bronze alloy may be used where steel would corrode rapidly. It usually contains about 5 per cent tin, a trace of phosphorus (added as phosphor-tin to prevent brittleness), and the remainder copper. The tensile strength obtained by cold drawing is about 95,000 pounds per square inch and the elastic limit about 50,000 pounds per square inch for wire of No. 8 B & S gage.

S.A.E. No. 80 Brass Wire: This cold-drawn wire is inferior in strength and corrosion resistance to phosphor bronze, but it may be used where cost of material is an important factor. Grade A, intended for severe operating conditions, contains 70 to 74 per cent copper, a maximum of 0.10 lead, a maximum of 0.06 iron, and the remainder zinc. Grade B, for ordinary requirements, has practically the same composition excepting the copper content which is 64 to 68 per cent.

Monel Metal: This alloy has excellent corrosion-resistant properties and will withstand abnormally high temperatures. Cold-drawn wire (spring temper) has a tensile strength of 145,000 to 175,000 pounds per square inch for "K" Monel. It

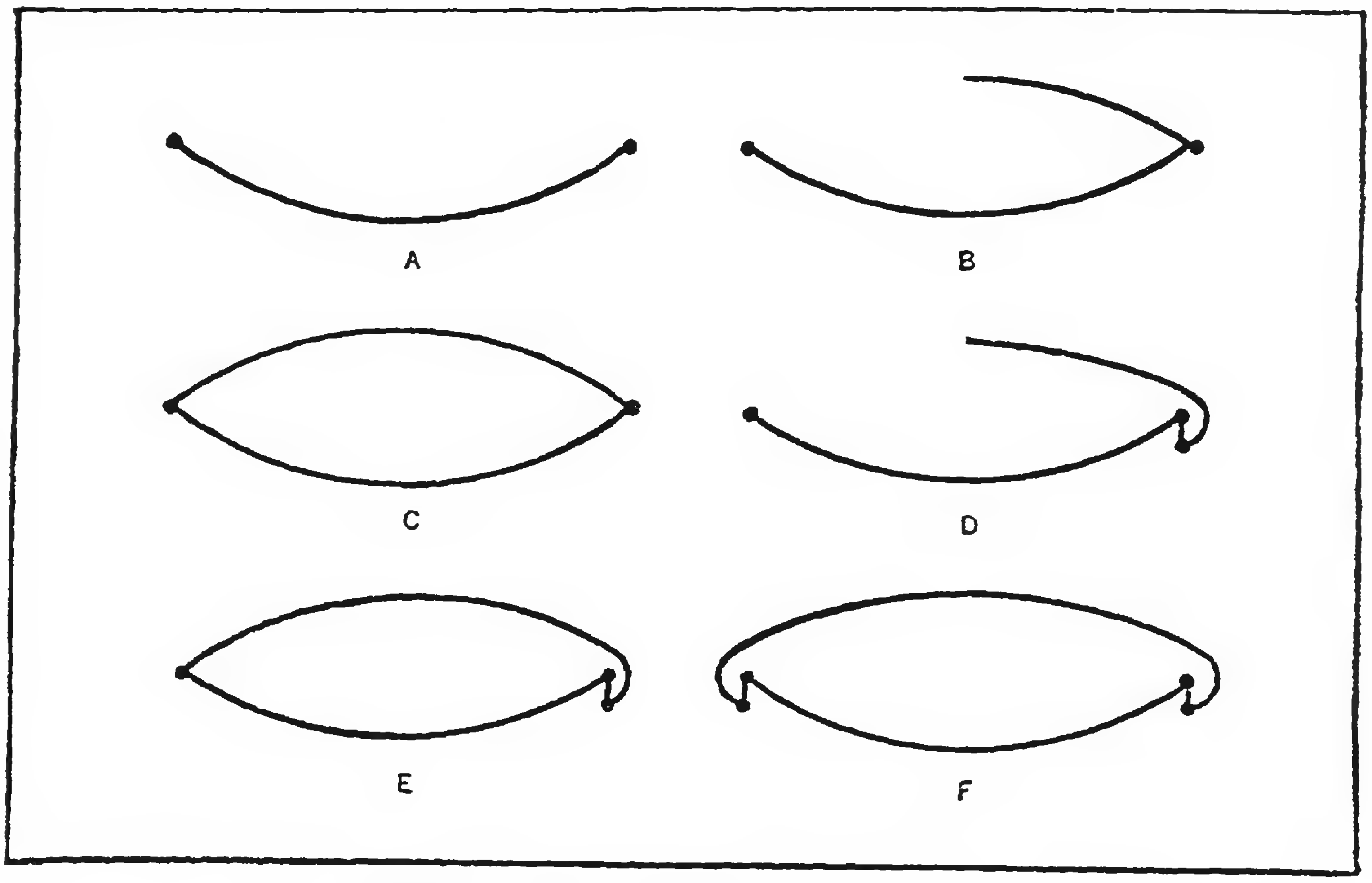
contains 66 per cent nickel, 29 per cent copper, 2.75 per cent aluminum, 0.9 per cent iron, 0.4 per cent manganese, and 0.25 per cent silicon.

Inconel: This is another high-nickel alloy which is exceptionally resistant to high temperatures and corrosion. The nickel content is 79.5; chromium, 13; iron, 6.5; copper, 0.2; silicon, 0.25; manganese, 0.25. The tensile strength of cold-drawn spring wire is 165,000 to 185,000 pounds per square inch.

Beryllium-Copper Wire: This alloy contains 2 to 2.25 per cent beryllium; 0.25 to 0.50 per cent nickel; usually less than 0.1 per cent iron; and the remainder copper. It has high resistance to fatigue and corrosion, and also high coefficient of electrical conductivity. The wire is cold drawn, and a low-temperature heat-treatment gives it a tensile strength of about 200,000 pounds per square inch.

Spring Plunger. This is a plunger actuated by a helical spring so that the plunger will always occupy a certain position except when pulled back by the hand or by some mechanical means.

Springs. The three principal types of springs are: 1. Flat springs. 2. Spiral springs. 3. Helical or coil springs. The *leaf spring* is simply built up from a number of flat springs of uniform rectangular cross-section. By making successive leaves



Different Types of Leaf-springs

shorter than each preceding leaf, the spring becomes a modification of a beam of uniform strength. These leaf springs are frequently so arranged that they are supported at both ends, having the load applied in the center. They are then generally curved, so that the load, when applied, tends to straighten them.

Elliptic Springs: Six classes of leaf springs are represented by the accompanying diagrams: Half or semi-elliptic spring, *A*, three-quarter elliptic spring *B*, consisting of quarter elliptic on top and half elliptic on bottom—joined at one end by a bolt; elliptic spring *C*, consisting of half elliptic on top and half elliptic on bottom—joined at both ends by bolts; three-quarter scroll elliptic spring *D*, consisting of quarter scroll on top and half elliptic on bottom—joined at one end by a shackle; scroll elliptic spring *E* (one end), consisting of scroll at one end on top, and half elliptic on bottom—joined at one end by a bolt and at the other by a shackle; scroll elliptic spring *F* (both ends), consisting of scroll elliptic at both ends on top, and half elliptic on bottom—joined at both ends by shackles.

Spiral Spring: This type is wound in the form of a spiral the most familiar use of this spring being in watches and clocks Spiral springs are employed where an angular movement is to be caused by the spring.

Helical or Coil Springs: Springs of this class are sometimes, although incorrectly, termed spiral springs. Helical springs are wound into a coil from round, square, or rectangular shaped wire or bars, the circular shape of wire being the most common. The *conical* or *helico-spiral* coil spring is a form which is often used on pump valves. Its main advantage as compared with an ordinary coil spring is that it does not easily buckle sidewise. A conical spring also has the advantage that if successive coils are enough smaller than those preceding them, it will, upon compression, close up flat between the constraining surfaces.

Springs, Coiling. The method employed for spring winding ordinarily depends upon the number of springs required and, to some extent, upon their form. When a comparatively small number of springs are needed in connection with repair work, etc., it is common practice to wind them in a lathe, whereas, when springs are manufactured in large quantities, special coiling machines are employed. When springs are wound in a lathe, the wire is coiled about an arbor the diameter of which should be determined by trial. Usually the arbor diameter should be about ⅞ of the required inside spring diameter. The arbor may be mounted between the centers or, in the case of short springs, be held in a chuck. Both extension or closed springs and compression or open springs may be wound in this way. For springs

made of wire 1/16 inch or less in diameter, the speed lathe is commonly used, whereas, for larger wire, it is preferable to use an engine lathe and drive through the back-gearing.

Some means must be provided in any case for subjecting the wire to sufficient tension while winding, to coil it tightly about the arbor. When winding a compression spring, the wire should also be traversed in the direction of the arbor, so that coils of uniform pitch will be formed; similarly, when winding an extension or "tension" spring, the feeding of the wire should be such that all of the coils will be close together, there being preferably a slight initial tension between the coils. Different forms of tools are used for obtaining the necessary tension on the wire and spacing of the coils while winding. In some cases, the tool is held rigidly in the lathe toolpost and the wire passes through a hole or slot so arranged that the friction and tension may be regulated. The spacing or pitch of the coils can be varied by gearing the lathe the same as for screw cutting, in order to give the carriage a traversing movement while winding the spring. For instance, if a compression spring were required having six coils to the inch, the lathe would be geared for cutting six threads per inch, the result being that, as the carriage moves along, the wire is coiled around the arbor at approximately the same pitch. There is another type of spring winder which is held by hand while the spring is being wound about the arbor, and the tool itself regulates the coil spacing.

Springs, Coiling Machines. The coiling of springs made in quantities is accomplished either by a standard spring-coiling machine, which may be adjusted to suit coil springs of various dimensions, or if the quantity of a particular type of spring desired warrants it by a special machine which coils, cuts, and hooks the spring in a single operation. Such a machine necessarily has a very limited range, and is found in automobile plants more often than in shops making springs for the trade in general. Standard spring-coiling machines may be classified as continuous coiling machines and coiling and cutting machines. In one machine of the latter type, designed for handling heavy wire, the length of the wire is controlled by the movement of a segment or by gears. The pitch may be automatically controlled so as to square the ends of the springs. This type of machine is used for extension springs as well as for compression springs. Conical and barrel shaped springs as well as springs of constant diameter and varying pitch also come within its scope. In the special machines, as in those for general manufacture, the operations consist of first straightening the wire by drawing it through a groove or rollers, and then coiling it by making it follow the

course directed by external rollers or by a combination of external rollers and an internal mandrel. In the coiling operation, the spring wire is automatically tested for uniformity, since hard spots in the wire will be indicated by a bumpy or uneven surface on the coiled spring.

Springs, Diameters. A helical or coil spring should have an outside diameter equal to from five to eight times the diameter of wire or bar from which the spring is made; under no circumstances should the outside diameter be made less than four times the diameter of the wire. The effective number of coils in a compression spring may be considered as two less than the actual number, owing to the squared ends of the spring.

Springs, Factor of Safety. When a spring acts only occasionally it can be safely designed to carry a load which causes a fiber stress nearly equal to the elastic limit of the spring, but, when the compressions or extensions are frequent, a larger factor of safety must be used. A valve spring in an automobile motor, for example, which operates, say, 200 times a minute, should have a factor of safety of at least 4. In other words, a spring, which ordinarily could be designed for a torsional stress of 100,000 pounds per square inch, should be designed to work at a stress not over 25,000 pounds per square inch when used in service of the kind mentioned. High-class springs, such as valve springs, should have the ends squared and ground at right angles to their axis; the outside diameter should be at least one-third of the length, and it should be supported its entire length, unless it is very short, in order to prevent buckling, which introduces bending and twisting strains. High-class valve springs when placed on end on a flat plate should not vary more than ½ degree from the perpendicular.

Springs, Formulas for Helical. The formulas which follow are for calculating the load, deflection, size of wire and fiber stress in helical springs made from round wire or rod. In these formulas, $P =$ load, in pounds $=$ safe working load when S is within allowable limits $=$ load required to compress spring solid when deflection F is maximum; $F =$ deflection, in inches, caused by given load $=$ total deflection from free to solid length when $P =$ solid height load; $S =$ fiber stress, in pounds per square inch; $D =$ mean diameter of spring, in inches $=$ outside diameter minus wire diameter d; $d =$ diameter of spring wire or rod, in inches; $K =$ Wahl factor, a correction factor which introduces greater accuracy into calculations involving fiber stress, espe-

cially where the ratio of $\frac{D}{d}$ is relatively small (see Wahl Factor); N = number of active or effective coils; and G = torsional modulus of elasticity in pounds per square inch.

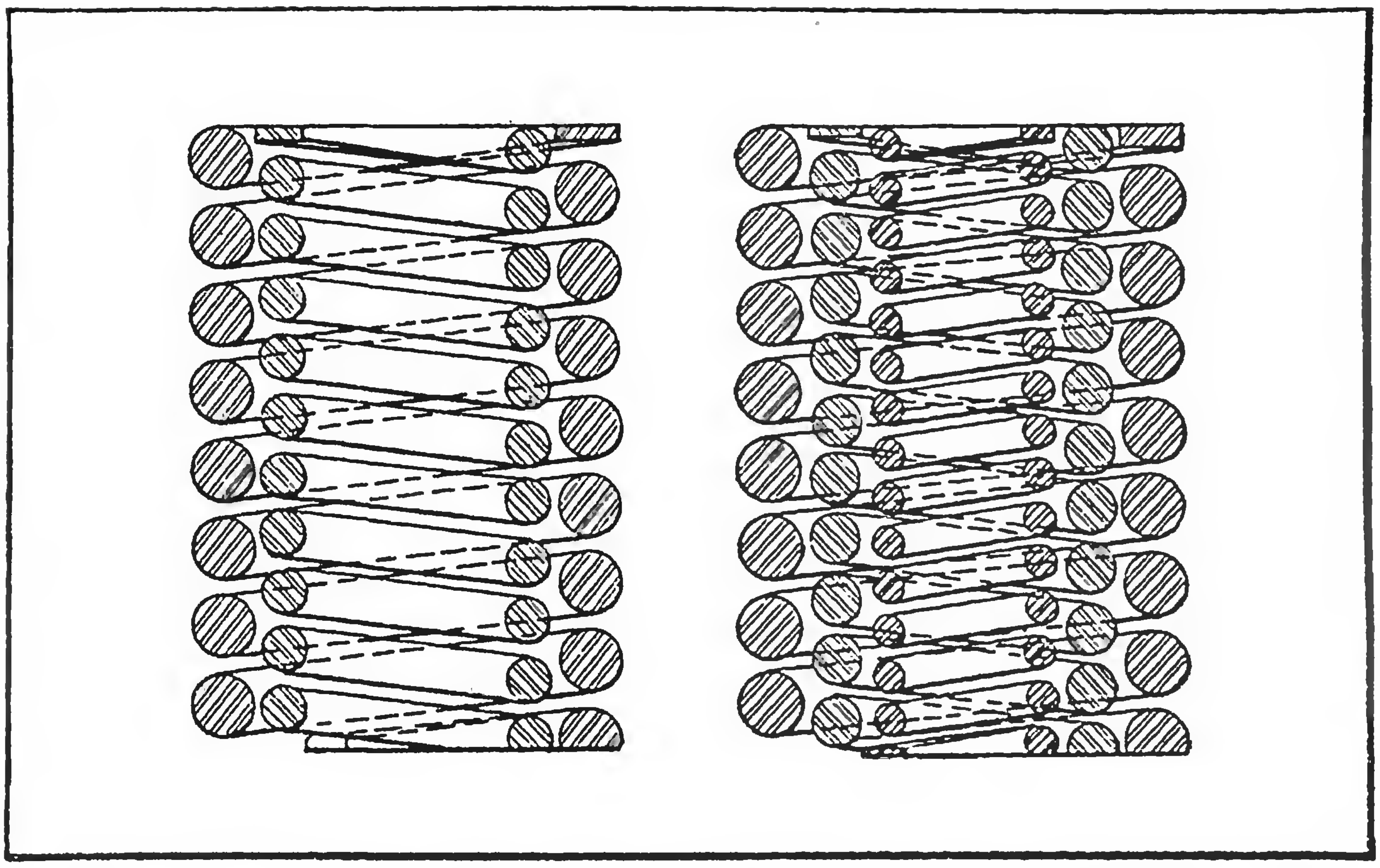
$$(1)\quad P = \frac{\pi S d^3}{8DK} \qquad\qquad (3)\quad d = \sqrt[3]{\frac{PD}{0.3S}}$$

$$(2)\quad F = \frac{8PND^3}{Gd^4} \qquad\qquad (4)\quad S = \frac{FGdK}{N\pi D^2}$$

Where S is the allowable safe working stress, its value will vary for different classes and grades of spring wire as will the value of G. For more exact calculations, the value of S used will also be affected by the size of wire. For average grades of material and not considering wire size, the following values may be used as an approximation: For oil-tempered commercial steel wire, G = 11,000,000 and S = 100,000 pounds per square inch for light service; use 80 per cent of this stress value for average service and 65 per cent of this stress value for severe service. For music wire, G = 12,000,000 and S = 120 per cent of the stress values for oil-tempered commercial steel wire. For hard-drawn steel wire, G = 11,000,000 and S = 80 per cent of the stress values for oil-tempered commercial steel wire. For stainless 18-8 steel, G = 10,500,000 and S = 80 per cent of the stress values for oil-tempered commercial steel wire. For phosphor bronze, G = 6,000,000 and S = 45 per cent of the stress values for oil-tempered commercial steel wire. For beryllium copper, G = 7,000,000 and S = 60 per cent of the stress values for oil-tempered commercial steel wire. For brass, G = 5,000,000 and S = 40 per cent of the stress values for oil-tempered commercial steel wire. For Monel metal, G = 9,250,000 and S = 50 per cent of the stress values for oil-tempered commercial steel wire.

Helical Springs Made of Square Wire: Helical springs usually are made of round wire. In some cases, however, wire of square cross-section may be used to obtain a higher load-carrying capacity without increasing the size of the spring. In designing square wire springs, the load and deflection for a given working stress may be calculated first for a round wire spring having the same diameter, number of turns, and a wire diameter equal to the side of the square cross-section; then the load capacity of the round wire spring is multiplied by 1.06 and the deflection by 0.739, in order to obtain corresponding values for a spring made of square wire.

While the load capacity of the square wire spring is 6 per cent greater than that of one made of round wire, the square wire has,



Double and Triple Coil Concentric Groups, showing Right- and Left-hand Coiling, to prevent Binding

of course, larger cross-sectional area and more material. If square wire springs are compared with round wire springs on the basis of load capacity per unit volume of spring material, the square wire capacity for a given stress is only about 83 per cent of the round wire. The round wire will store about 1.27 times as much energy as the square wire, notwithstanding its smaller area. If spring efficiency is expressed as energy stored per unit volume of spring material, then round wire is 62 per cent more efficient than square wire.

Springs, Multiple or Group Type. The accompanying illustration shows grouped or "nested" springs. The object is to increase the carrying capacity within a given space. The outer and inner coils are made with a different direction of helix, in order to prevent binding. In a spring concentrically arranged, the inner bars are the smaller, and the greatest load is naturally upon the outer spring. There is a point, however, beyond which more inner coils will cease to be of advantage owing to the small gain in capacity. The addition of outer coils is also soon limited by the impossibility of coiling and tempering large bars. It is, therefore, evident that the load which may be carried by the concentric group is limited.

Where greater capacity is desirable than can be obtained by concentric grouping, several single coils, or several concentric groups, may be held together between spring plates. Such groups

naturally offer greater stability than concentric groups; but, where the concentric group affords sufficient capacity and stability, it should be used, as it is more economical of space and does not necessitate the use of spring plates to hold the different coils together. The designing of groups of this kind consists in the simple operation of dividing the load into as many parts as there will be units in the group.

Springs, Nickel Alloy. For springs which are exposed to dampness or chemicals that cause them to rust and corrode, monel metal has been used satisfactorily. This metal has a torsional strength of 80,000 pounds per square inch, a torsional modulus of 9,250,000, a tensile strength of 135,000 pounds per square inch, and a tensional modulus of 25,000,000. The safe working stress in torsion for monel metal in cases where fatigue is not a factor is said to be 70,000 pounds per square inch. In cases where fatigue is a factor and it is desired that the spring shall operate 2,000,000 times without fracture, a safe working stress in torsion of only 30,000 pounds per square inch should be employed.

Inconel is another high-nickel alloy which is exceptionally resistant to high temperatures and corrosion. The nickel content is 79.5; chromium, 13; iron, 6.5; copper, 0.2; silicon, 0.25; manganese, 0.25. The tensile strength of cold-drawn spring wire is 165,000 to 185,000 pounds per square inch.

Spring Steels. In general, steel wire springs may be divided into two classes—those that are coiled from spring tempered wire and given no subsequent heat-treatment (unless it be a slight draw, which partially removes the internal strains produced by cold working) and those that are coiled from annealed wire and afterward given a complete thermal treatment to impart the proper spring temper. The first method is obviously the cheaper, and hence is used for the majority of machine springs. The latter method, though more expensive, permits better control of the final state of the steel, and is used on many of the more expensive engine valve springs as well as on practically all springs used in measuring instruments. In both classes of springs the methods of manufacture, with the exception of the heat-treatment, are almost identical.

S.A.E. 1060: This grade of steel is used for valve-springs, hard-drawn spring wire and coil springs for general purposes. For heat-treated springs, a hardness of C45 to C50, Rockwell, is usually recommended.

S.A.E. 1066 (old No. X1065): This steel is applicable to coil springs of hard-drawn or oil-tempered wire and heat-treated

springs. For heat-treated springs, a hardness of C40 to C48, Rockwell, is usually recommended.

S.A.E. 1095: This grade of steel is used for carbon steel leaf springs, and coil springs.

S.A.E. 9260: This steel has been standardized in usage principally for leaf springs. It is generally the practice to specify manganese on the high side of the range for leaf spring sections of ⅜ inch or over and the low and medium manganese for sections under ⅜ inch.

Chromium-Vanadium Steel: This spring steel is superior to the straight carbon steel in toughness and when the operating temperature is too high for carbon steel. It contains from 0.45 to 0.55 carbon, 0.50 to 0.80 manganese, 0.90 to 1.20 chromium, 0.10 to 0.20 silicon, 0.15 to 0.20 vanadium. This steel is supplied either in the tempered or annealed condition. It is adapted to valve springs or wherever there are repeated stresses. The tensile strength varies from 200,000 to 300,000, and the elastic limit from 160,000 to 250,000 pounds per square inch.

Stainless Steel: This steel not only has high resistance to corrosion, but retains its strength in temperatures up to 700 degrees F., or even higher. For hard-drawn wire, the carbon content is 0.12, with chromium ranging from 17 to 20 and nickel 8 to 10 per cent. If supplied in the annealed condition for heat-treatment after coiling, the carbon content may vary from 0.30 to 0.40 per cent. The ultimate strength ranges from 150,000 to 280,000, and the elastic limit from 75,000 to 150,000 pounds per square inch.

Sprocket Adjustable Radially. Sprockets of the adjustable type have teeth that may be adjusted radially from time to time to compensate for wear and consequent elongation of chain links. After the chain has elongated beyond a correct fit on the sprocket, nuts are released and eccentric blocks readjusted so as to expand the teeth to the next larger pitch diameter provided for. As a rule, adjustments are not required often.

Sprocket, Gap Type. This is a type of sprocket used for link-belting and employed in cases where the reverse side of the chain runs against the sprocket. When the chain is fitted with some attachment for specific purposes and a reverse bend is required, the sprocket must be provided with a gap or gaps to allow the attachment to pass.

Sprockets. When a driving and driven shaft are connected by a chain type of transmission, the chain intermeshes with and operates over toothed wheels known as sprockets. The pitch of

the sprocket teeth depends upon the pitch of the chain used. The American Standard for roller chains includes pitches ranging from 3/8 inch up to 3 inches.

Pitch Diameter: The pitch diameter of a sprocket (especially sprockets having a small number of teeth) must not be figured in the same way as that of spur gear diameter based on the circular pitch. For a sprocket, the pitch length of the chain links must be considered as a chord, whereas the circular pitch of a gear is measured along an arc.

$$\text{Pitch diameter of sprocket} = \frac{\text{Pitch of chain}}{\sin\ (180 \text{ degrees} \div N)}$$

Outside Diameter: The outside diameter may be determined by the following formula in which O = minimum outside diameter; P = pitch of chain; N = number of sprocket teeth.

$$O = P\left(0.6 + \cot\frac{180°}{N}\right)$$

The base or *bottom diameter* of a roller-chain sprocket equals the pitch diameter minus the diameter of the roller.

Caliper Diameter: If a sprocket has an odd number of teeth, the modified bottom diameter for calipering the sprocket may be determined by the following formula, in which D = the roller diameter:

$$\text{Caliper Diameter} = \left(\text{Pitch diameter} \times \cos\frac{90°}{N}\right) - D$$

Roller Diameter: The roller diameters equal or approximately equal Pitch of chain × 0.625 and range from 0.200 inch up to 1.90 inch in the American Standard.

Sprocket Cutting: Sprocket teeth may be cut (1) by milling with a formed cutter; (2) by hobbing; (3) on a Fellows gear shaper. The American Standard includes the dimensions of formed milling cutters—both "space cutters" and the "straddle" form. The space cutter mills the space between two teeth. The straddle cutter straddles a tooth and mills both sides, and that half of the bottom surface adjacent to the tooth on each side.

Space Cutters: Five cutters of this type will be required to cut from 7 teeth up for any given roller diameter. The ranges are respectively 7-8, 9-11, 12-17, 18-34, and 35 teeth and over. If less than 7 teeth is necessary, special cutters conforming to the required number of teeth should be used.

Straddle Cutters: Two of these cutters (designated as A and B) will be required to cut from 7 teeth up for any given pitch and roller diameter. Cutter A is based on 40 teeth and is designed to be used for 18 teeth and over. The maximum pressure angle

is 32 degrees and the average pressure angle is 23.7 degrees. Cutter *A* is recommended for less than 18 teeth if a large pressure angle is desired and the arc of contact between chain and sprocket is fairly large. Cutter *B* is recommended for 17 teeth and under, or for more than 17 teeth if a low pressure angle is desired. Cutter *B* is based on 11 teeth. The maximum pressure angle for new chain is 24.1 degrees and the average pressure angle is 17.6 degrees.

Hobs: Only one hob will be required to cut any number of teeth for a given pitch and roller diameter.

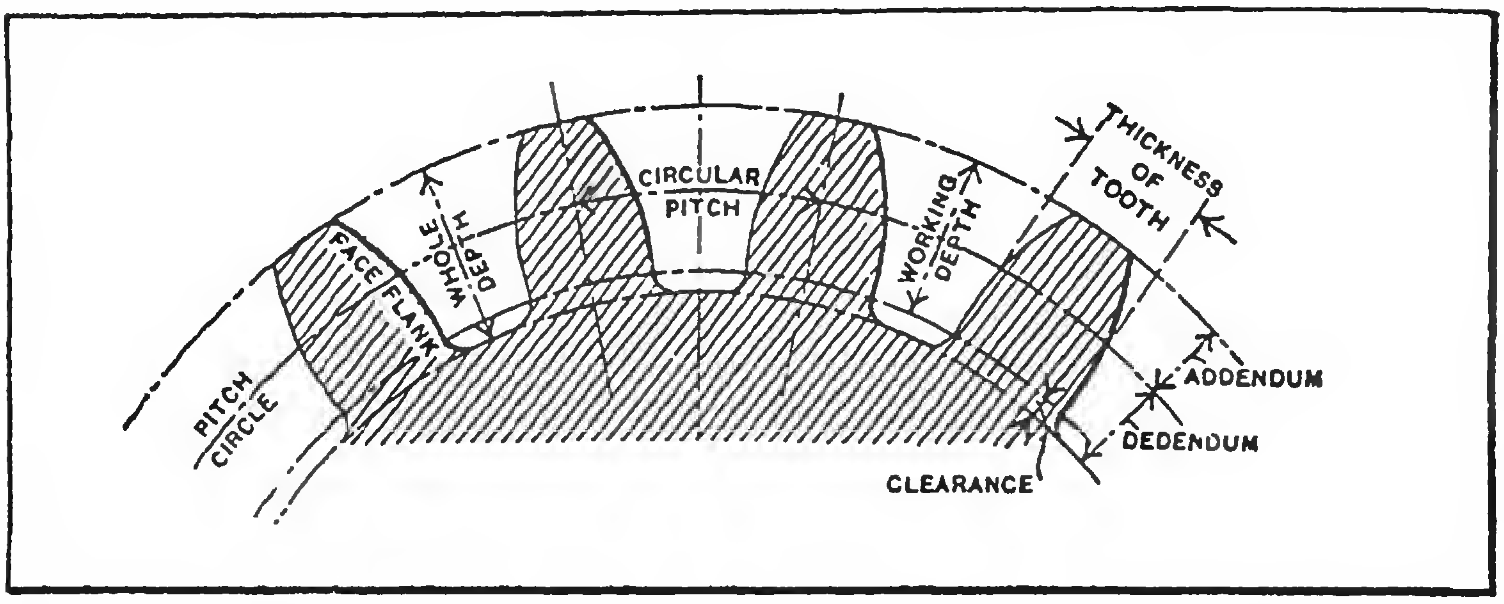
Fellows Cutters: These are for use on the Fellows gear shaper. Not more than two will be required to cut any number of teeth for a given pitch and roller diameter.

Sprue on Drop-Forging. Drop-forgings ordinarily are made complete while still a part of the bar of stock. To hold the forging while being worked, a *sprue* must be provided. The sprue is the connecting link between the bar of rough steel and the forging. To form the sprue, a channel is cut from the front end of the impression to the edge of the die-block. The size of the sprue should be governed by the weight of the forging, and in all cases it should be no heavier than is necessary to support the forging while being worked and trimmed. The *gate* is an opening in the front of the die to receive the bar stock.

Spur Gearing. The type of toothed gearing in which the teeth are formed on the cylindrical surface of the gear blank and are parallel to the axis of rotation of the gear, is known as "spur" gearing. The pitch circles of two spur gears in mesh (which are, of course, imaginary circles) always intersect the common center-line at the point where the line of action crosses this center-line. The term *pitch diameter* as ordinarily applied to gearing means that diameter obtained by dividing the number of teeth by the diametral pitch; both the pitch diameter and the pressure angle, as these terms are ordinarily applied, relate to the diameter and angle corresponding to standard center-to-center distances. The *root diameter* of a gear is the diameter measured at the bottom or roots of the teeth. The *diametral pitch* of a gear is the number of teeth for each inch of pitch diameter, and is found by dividing the number of teeth by the pitch diameter. The *circular pitch* is the distance from the center of one tooth to the center of the next along the pitch circle. (See diagram.) The *chordal pitch* is the distance from the center (on the pitch circle) of one tooth to the center of the next, measured along a straight line. The *thickness* of the tooth is generally understood to be the thickness at the pitch circle.

The *chordal thickness* of the tooth is the thickness at the pitch circle measured along a straight line or chord. The *addendum* of a gear tooth is the distance from the pitch circle to the top of the tooth. The *dedendum* of a gear tooth is the distance from the pitch circle to the root of the tooth. The *working depth* is the depth to which the teeth in a meshing gear enter into the spaces between the teeth.

The *clearance* is the amount by which the tooth space is cut deeper than the working depth.



Spur Gear Tooth Parts

The *face* of the tooth is that part of the tooth curve that is between the outside circumference and the pitch circle.

The *flank* of the tooth is that part of the working depth of the tooth which comes inside of the pitch circle.

Spur Gear Power Transmitting Capacity. The amount of power which can safely be transmitted by a pair of gears running at a given speed depends upon the allowable tooth load. This allowable load may be determined with reference to the strength of the teeth or it may be established with reference to tooth wear.

Lewis Formula: The Lewis formula (introduced by Wilfred Lewis in 1892) has been used extensively for determining the power transmitting capacity of gearing. This formula, which is based upon the beam strength of the teeth, gives very conservative values especially when applied to high-speed gearing produced by the accurate equipment now available. All of the factors required in determining the power capacity of gearing may be combined into a single formula like the one following which is based upon the original Lewis formula and gives the same power rating.

$$\text{H.P.} = \frac{S_s \times F \times V \times Y}{P \times 55 \times (600 + V)}$$

In this formula,

V = velocity in ft. per min. at pitch diameter;
S_s = allowable static unit stress for material;
F = width of face in inches;
Y = outline factor;
P = diametral pitch (if circular pitch is given, divide 3.1416 by circular pitch to obtain diametral pitch);
H.P. = maximum safe horsepower.

The power-transmitting capacity as determined by the Lewis formula usually is less than the actual amount which could be transmitted safely, and in many cases it is considerably below the actual capacity. This is particularly true of accurate high-speed gearing. The formula which follows is less conservative than the original Lewis formula. It is arranged to reduce the load as the velocity increases by using the approximate equivalent of the speed factor $1200 \div (1200 + V)$ instead of the factor $600 \div (600 + V)$.

$$\text{H.P.} = \frac{S_s \times F \times V \times Y}{P \times 27 \times (1200 + V)}$$

Diametral Pitch for Given Power Capacity: The preceding formulas are arranged to indicate the approximate safe power-transmitting capacity of a pair of gears. In the design of gearing, however, it may be necessary to determine the pitch or tooth size required for transmitting a given number of horsepower. If the power rating is based upon the original Lewis formula, the equivalent diametral pitch P is found by the following formula:

$$P = \frac{S_s \times F \times V \times Y}{\text{H.P.} \times 55 \times (600 + V)}$$

The face width of a spur gear usually equals three to four times the circular pitch or face width = circular pitch $\times\ k$ with k varying from 3 to 4. Theoretically, the power-transmitting capacity increases in proportion to the face width, but this only holds true within certain practical limits because very wide gearing may not have proper contact throughout the length of the teeth, possibly because of deflections or imperfect mounting. If a face width of 4 times the circular pitch is considered satisfactory, then in the following formula k should equal 4. The formula

will then show the diametral pitch required when the face width equals 4 times the circular pitch.

$$P = \sqrt{\frac{3.1416 \times S_s \times k \times V \times Y}{\text{H.P.} \times 55 \times (600 + V)}}$$

Load at Pitch Line and Equivalent Horsepower: When gears transmit a given number of horsepower, the equivalent load in pounds at the pitch line is found as follows:

$$\text{Load at pitch line} = \frac{\text{H.P.} \times 33{,}000}{V}$$

$$\text{also, H.P.} = \frac{\text{load at pitch line} \times V}{33{,}000}$$

In the second formula, if the load at the pitch line is the allowable or safe load as limited either by tooth strength or tooth wear, then the second formula will indicate the safe or allowable number of horsepower which can be transmitted. The main problem, then, in estimating the power capacity of gearing is to determine the allowable load. This load depends upon such factors as the material of which the gear and pinion are made, the heat-treatment if any, the operating speed, the face width within reasonable or practical limits, the pitch of the teeth and their shape which varies with the number of teeth.

Spur Gear, "Twisted." See Twisted Spur Gear.

Square Engine. This is a term sometimes employed to describe an engine that has a stroke equal to the diameter of the piston. For example, an engine having an 8-inch diameter and 8-inch stroke would be an 8-inch square engine.

Square File. This style of file either tapers from the middle toward the point or is made of uniform cross-section throughout. The taper square file has double-cut, bastard teeth, and is extensively used in machine shops generally, principally for enlarging apertures of a square or rectangular shape. The blunt form also has double-cut bastard teeth and is employed by engine builders and in the shops of railroads, ship-yards, etc., for the rougher work in finishing or enlarging mortises, keyways, or splines, especially when of considerable length.

Square Hole Drills. See Drills, Angular Hole.

Square-Jaw Clutch. This is a positive clutch provided with teeth having perpendicular or square sides, so that, when engaged, the clutch will drive in either direction. Clutches of this type cannot be engaged and disengaged readily unless stationary or revolving slowly.

Square Measure. 1 square mile = 640 acres = 6400 square chains; 1 acre = 10 square chains = 4840 square yards = 43,560 square feet; 1 square chain = 16 square rods = 484 square yards = 4356 square feet; 1 square rod = 30.25 square yards = 272.25 square feet = 625 square links; 1 square yard = 9 square feet; 1 square foot = 144 square inches. An acre is equal to a square, the side of which is 208.7 feet.

Square Root. The square root of a given number or quantity, is that number or quantity which, when multiplied by itself, will give a product equal to the given number. If the given number is 81, the square root is 9, because $9 \times 9 = 81$. The sign $\sqrt{}$ indicates that the square root is to be extracted. Thus $\sqrt{81} = 9$.

Square Thread. The square thread is so named because the section is square, the depth, in the case of a screw, being equal to the width or one-half the pitch. The thread groove in a square-threaded nut is made a little greater than one-half the pitch in order to provide a slight clearance for the screw; hence, the tools used for threading square-threaded taps are a little less in width at the point than one-half the pitch. The pitch of a square thread is usually twice the pitch of an American Standard thread of corresponding diameter. The square thread has been superseded quite largely by the Acme form which has several advantages. See Acme Thread.

Squaring Shears. Squaring shears, for cutting sheet tin, iron, brass, copper, aluminum, etc., are of the foot-treadle or power-driven types. They have one fixed cutting blade, which is usually the lower blade and attached to the bed of the machine, and one movable blade attached to the cross-head or gate which is guided in vertical slides. Side gages are provided that can be bolted square with the cutting blades for guiding the sheet metal for squaring operations, and long bed gages that can be bolted parallel to or at an angle to the cutting blades, in the front or in the rear of the machine, for guiding the cutting of the metal to the lengths required. On power squaring shears the stroke of the cross-head is controlled by means of an automatic clutch. The clutch is tripped with a depression of a foot-treadle, and unless the treadle is kept depressed the motion of the cross-head will stop automatically at its highest point. When the side housings or frame of a squaring shear is shaped with a throat or gap so as to permit the handling of sheets of a width greater than the width of the machine, the shears are known as *gap squaring shears*.

Stage. In air compression, the term stage refers to the different steps in which air is compressed in multi-stage compressors, the air being compressed first in one cylinder to a certain

pressure and then passed to another cylinder where it is compressed to a higher pressure. It is generally passed through an intercooler between the two cylinders, where it is cooled to its initial temperature before the second stage of compression.

Stagger-Feed Press. A punch press equipped with a stagger feed is so arranged that the punch cuts blanks in a staggered relation to one another, thus reducing waste and utilizing the stock to the greatest extent. Such a feed is especially suitable for the production of such parts as can tops and bottoms and other small shells. The sheet stock is held in a carrier which travels past the reciprocating punch. The stagger feed may be so designed that it is not necessary for the carrier to be returned to the starting point after punching a row of blanks, because the moment the end of a row has been reached the action of the carrier is automatically reversed and the next row may be punched as the carrier returns to the starting point.

Stainless Iron. The name "stainless iron" is rather misleading as it relates to a very mild stainless steel which forms the lowest carbon member of a series of steels of continuously varying content which are, in many respects, the counterpart of the series of ordinary carbon steels ranging from "dead soft" to tool steels. Because of its greater softness, stainless iron forges more easily than the harder varieties of stainless material; it works probably as easily as ordinary steel containing about 0.4 per cent carbon and hence may readily be forged, rolled, or drop stamped.

Stainless Steel. The expression "stainless steel" is a trade name that has been applied to a low-carbon alloy steel of high chromium content, which possesses to a remarkable degree the property of resisting corrosion. The chromium content of ordinary stainless steel may vary from about 9 to 20 per cent. This steel was originally developed for use in the cutlery trades, because it neither rusts nor tarnishes when in contact with food and many fruit acids; hence, the name "stainless." See Corrosion-resistant Steels.

Stainless Steel Castings. Castings made from stainless steel possess the corrosion-resisting characteristics common to stainless iron and steel in sheet and rolled form. Stainless steel castings are especially adapted for use in the chemical industry for resisting various acids and chemicals, or wherever castings are subjected to unusual corrosion or attacks from injurious elements. Castings of this kind are commonly used for such parts as valve bodies, pipe fittings, stirring devices for chemical apparatus, chemical still bottoms, centrifugal pump impellers for water and corrosive chemicals or liquids, and, owing to corrosive resistance against the action of sea water, for pump bodies, dock

sluice gates, etc. Most stainless steel castings have a chromium content ranging from 13 to 18 per cent. Castings of this kind may be machined readily and fine finishes obtained. The contraction of stainless castings is somewhat greater than that of ordinary steels and is about 9/32 inch per foot. Very thin flanges and webs should be avoided if possible. Under ordinary conditions, the minimum thickness should be 3/8 inch, although in special cases thinner sections can be allowed.

One of the most important properties of stainless steel, especially in connection with the chemical industries, is its immunity to attack by nitric acid. Steels of this class also resist oxidation at temperatures of from 1500 to 1800 degrees F. and even higher temperatures, depending upon the percentage of chromium in the alloy. Because of this property, stainless steel castings are especially adapted for certain furnace parts. In this connection, the chrome-iron alloys offer a high degree of immunity to sulphur corrosion. In this respect they are superior to the nickel-chromium-iron compositions in which nickel is the predominating alloying element, because the nickel is rapidly converted into nickel sulphide. This immunity to sulphur corrosion is particularly of importance where furnaces are operated with high sulphur fuel oil or producer gas from high sulphur coals. According to a manufacturer of stainless steel castings there is a marked tendency toward grain growth at temperatures exceeding 1500 degrees F. and when the chromium percentage exceeds 20 per cent, the castings become very brittle and somewhat unreliable as to physical properties. These defects may be minimized by the introduction of a small amount of nickel which is of great benefit for general commercial applications and does not detract greatly from the corrosion-resisting qualities of the alloy; however, even small nickel additions are objectionable for parts subjected to nitric acid. If castings are intended for nitric acid work, the qualities of ductility and machinability are obtained by keeping the carbon content under 0.20 per cent and annealing the casting before machining. Castings containing from 16 to 18 per cent chromium have an ultimate tensile strength, according to a manufacturer, close to 100,000 pounds per square inch, whereas castings of higher chromium content (27 to 30 per cent) have an ultimate tensile strength of 40,000 to 50,000 pounds per square inch.

Standard Cell. A primary cell used for obtaining a certain standard value of electromotive force under given conditions is known as a standard cell. To avoid polarization, standard cells are usually connected in series with high resistance, so that only a small current is obtained. Two common types of standard cells are the Clark and the Weston.

Standard Screw Thread. A standard thread conforms to an adopted standard in regard to the form or contour of the thread itself, and as to the pitches or numbers of threads per inch for different screw diameters. A screw thread having either a modified form or a pitch which is either greater or less for a given screw diameter than the adopted standard, is special.

Standard of Length. In 1866, Congress passed a law making legal the meter, the first and only measure of length that has been legalized by the United States Government. In May, 1875, representatives of various countries signed a treaty providing for the establishment and maintenance, at the common expense of the contracting nations, of a "scientific and permanent International Bureau of Weights and Measures, the location of which should be Paris, to be conducted by a general conference for weights and measures, to be composed of the delegates of all the contracting governments." This bureau was empowered to construct and preserve the international standards, to distribute copies to the several countries, and also to discuss and initiate measures necessary for the determination of the metric system. Thirty-one metric standards were made, and each country contributing to the support of the International Bureau received copies. The distribution was made by lot, the United States receiving Nos. 21 and 27. The international meter adopted by the Bureau was declared, by a formal order of the Secretary of the Treasury in 1893, to be the *fundamental unit of length* in the United States.

The primary standard is deposited at the International Bureau of Weights and Measures near Paris. This platinum-iridium bar has three fine lines at each end; the distance between the middle lines of each end, when the bar is at a temperature of 0 degree C., is one meter, by definition.

The United States yard is defined by the relation, 1 yard $= \frac{3600}{3937}$ meter. The legal equivalent of the meter for commercial purposes was fixed as 39.37 inches, by law, in July, 1866, and experience having shown that this value was exact within the error of observation, the United States Office of Standard Weights and Measures was, in 1893, authorized to derive the yard from the meter by the use of this relation. The United States prototype meters Nos. 27 and 21 were received from the International Bureau of Weights and Measures in 1889. Meter No. 27, sealed in its metal case, is preserved in a fireproof vault at the Bureau of Standards. No. 21 is occasionally used to verify the secondary or working standards of the Bureau, and, in special cases, where the highest accuracy is required, other meters are compared with it. The Bureau also possesses two other platinum-iridium standards, known as Nos. 4 and 12. The former is divided into millime-

ters for its entire length, and, in addition, is ruled with a special line to define the yard. For the routine work of testing, use is made of secondary or working standards the values of which are carefully determined by comparison with prototype meter No. 21, from time to time, to detect any possible changes. These working standards include multiples and sub-multiples of the meter and of the yard. See Light Wave as Length Standard.

Metric Equivalent of Inch: The equivalent of the meter as legalized by the United States Government, according to which 1 meter = 39.37 inches makes the metric equivalent of 1 inch = 25.4000508 + or practically 25.4 millimeters. The use in industry of 25.4 millimeters as a simplified practical equivalent of one inch has been approved by the American Standards Association. This equivalent has also been adopted by industry in Great Britain (where the legal equivalent of one inch is 25.39998 millimeters) and in Germany, Italy, Russia, Switzerland, Sweden, and other countries.

Standards of Weights and Measures. Originally the Bureau of Standards was mainly a government agency that preserved for comparison and duplication the standards of length and weight (mass). This function the Bureau still retains, in addition to its many other activities. In what is known as the "standard vault" are preserved the national standards of length and weight. Here is a standard meter made in 1797, and a yard made about 1830, as well as standard weights dating back to the early part of the past century. In addition, there are many standards made at a later date. The length and weight comparators are kept in a "constant temperature room," and are used for fundamental comparisons of length and mass under conditions controlled so that the highest precision can be obtained. The standards with which comparisons are made can be kept at a constant temperature within 0.1 degree F. A comparator is also available for standardizing precision steel tapes, such as are used in very accurate surveys. The room in which this work is done can be kept at any temperature from 32 to 110 degrees F. The Bureau also cooperates with the state and local authorities for the inspection of trade weights and measures, by annual conferences with the officials engaged in such work, by the distribution of handbooks relating to the technical details of weight and measure inspection work, and by consultation and correspondence.

Standard Wire Gage. This refers to the standard British wire gage, generally abbreviated S. W. G., legalized in Great Britain by Order in Council, August 23, 1883. It is also known as the "New British Standard wire gage," abbreviated N. B. S., and as the "British Legal Standard wire gage," and the "Imperial wire gage."

Standard Balance. This is the same as static balance.

Star Feed. A star feed is an intermittent feeding device used on certain machine tools. The star wheel which is a spoked wheel resembling a large-toothed spur gear (usually four or so teeth) is located at the end of the feed screw. A pin on a boring bar or similar tool engages a spoke on the wheel and thereby advances the feed screw a portion of a revolution.

Starting Switches. See Motors, Control Equipment.

Static Balance. If a circular part, such as a cylindrical drum or pulley, were mounted in bearings in which friction was practically eliminated, and with the axle in a horizontal position, it is evident that if one side were even slightly heavier than the other this unbalanced side would be at the bottom or lowest point possible when the drum or pulley came to a state of rest. If this same part were brought to such a state of balance that it would remain standing when turned about its axis to any position, it would be in *standing* or *static* balance; it does not necessarily follow, however, that this part would be in a balanced state when revolving, although if it has a running balance it will also be balanced statically.

Static Electrical Phenomena. The term *static* is applied to certain phenomena of an electrical nature which relate to the effect of electrical charges or electricity at rest, in contradistinction to electricity in motion or electric currents. The unit of electric charge (or quantity of electricity) is called a coulomb and an electric charge in motion constitutes an electric current.

Any material or object may be made to carry an electric charge if a sufficient potential is applied to it and if it is sufficiently insulated from other materials or objects to which the charge might be dissipated. Such electric charges may be positive or negative, and bodies carrying like charges tend to repel each other, while bodies carrying unlike charges are attracted, in each case inversely proportional to the square of the distance between the charges and directly proportional to the product of the charges.

If two elements carrying an unlike electrical charge are separated by a non-conductor such as air, a so-called electro-static field or condition of electrical strain is set up in this medium. If the static charges producing this field become excessive, the insulating medium—whether solid, liquid or gas—will break down and an electric current will flow. This current will be momentary if the charge is quickly dissipated, or sustained if a continued potential difference between the two elements is maintained, as in the case of a condenser subjected to continued excessive voltage in an electric circuit.

Static Pressure. See Blower Pressures.

Static Transformer. See Transformer.

Stayblade Max. Will resist oxidation in air and steam up to temperatures as high as 1650 degrees F. Said to be easily machinable. Contains high percentages of chromium and nickel, as well as titanium and aluminum. Intended for boiler drums, turbine casings, high-temperature reaction vessels, and other equipment operating at high temperatures and under great stress. Also used for blades in high-temperature turbines.

Staybolt. A staybolt is a bolt used in boilers and locomotives for supporting or staying the tube sheets. Staybolts are threaded throughout their length and are inserted in tapped holes in the inner and outer sheets. The ends are riveted over to tighten and strengthen the bolt.

Staybolt Iron. A wrought iron used for boiler staybolts, made entirely from puddled charcoal iron free from any admixture of iron scrap or steel, having a tensile strength of from 49,000 to 53,000 pounds per square inch.

Staybolt Steel. A steel employed for boiler staybolts, made by the open-hearth process, and having a tensile strength of from 50,000 to 60,000 pounds per square inch.

Staybolt Taps. A tap having 12 threads per inch, provided with a long shank and reamer section, for use by boiler makers in tapping boiler sheets preparatory to inserting the staybolts. It is generally driven by an air drill.

Spindle Staybolt Taps: A short tap with a hole drilled through its entire length, in which a spindle is fitted and acts as a guide. The tap is used for tapping holes from the inside of fire boxes in locomotive work.

St. Croix Rule. This is a rule employed for finding the board measure of logs, as follows: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply the result by the length of the log in feet; usually the diameter inside of the bark at the small end is measured.

Steadyrests for Grinding. Practically all parts that are ground on centers should be supported by suitable steadyrests or back-rests, as their use will not only obviate chattering, when properly applied, but permit taking deeper cuts with coarser feeds and also increase the "sizing power" of the wheel. In grinding long and slender parts, such supports are indispensable, and, even for work which is short and rigid, steadyrests are desirable to prevent vibration, which increases wheel wear and affects the quality of the ground surface. These supports are

fastened to the table of the machine and are equipped with shoes of hardwood or metal which bear against the piece being ground. The number of steadyrests used depends upon the form and diameter of the work. According to a commonly accepted rule, the distance between the steadyrests should be from six to ten times the diameter of the part being ground. Some recommend the use of as many rests as can conveniently be fixed in position.

Steadyrests for Turning. Occasionally long slender shafts, rods, etc., which are to be turned, are so flexible that it is necessary to support them at some point between the lathe centers. An attachment for the lathe known as a "steadyrest," is often used for this purpose. The common form of steadyrest is composed of a frame containing three jaws that can be adjusted in or out radially to suit the diameter of the work. The frame is hinged at one side, thus allowing the upper half to be swung back for inserting or removing work. A *follow-rest* differs from a steadyrest in that it is attached to and travels with the lathe carriage so that the support remains adjacent to the turning tool, which is especially important in turning shafting or other long parts.

Steam. Steam is water changed to a gaseous form by the application of heat. It may be either *saturated, superheated, dry* or *wet.* Saturated steam is that which is in the presence of, and at the same temperature as, the water from which it was evaporated. There is always a definite relation between the pressure and temperature in the case of saturated steam. For example, saturated steam evaporated under atmospheric pressure always has a temperature of 212 degrees F. Steam evaporated under a pressure of 5 pounds (gage) has a temperature of 228 degrees F.; under 10 pounds pressure, 240 degrees F.; under 100 pounds, 338 degrees F., and so on. *Superheated steam* is that which has been heated to a temperature above that due to its pressure. Steam is superheated by passing it through pipes or coils exposed to the hot gases from the furnace, after it leaves the steam space of the boiler. Engines and turbines are supplied with superheated steam, under favorable conditions, in order to obtain a higher efficiency. *Dry steam* is that which contains no moisture. It may be either saturated or superheated. *Wet steam* contains more or less moisture in the form of spray; in other ways it does not differ from saturated steam, having the same temperature at different pressures.

Steam Quality: The percentage of dry steam in steam containing moisture is called the quality of the steam. For example, if a pound of a given sample of steam contains 0.04 pound of water in the form of spray, and 0.96 pound of dry saturated

steam, the quality is said to be 96 per cent. It is very important to know the quality of the steam when testing a boiler for capacity and fuel consumption, as water carried over in the form of spray has no value for the generation of power in a steam engine, or for heating purposes. As the quantity of steam evaporated in a given time is found by weighing the feed water, it is evident that the moisture contained in the steam will appear in the result, unless its percentage is known and the necessary correction made. The proportion of moisture in steam is found by means of a device called a calorimeter, which forms an important part of the equipment used in boiler testing.

Steamboat Origin. Although Robert Fulton was not the first man to build a steamboat, the *Clermont*, which he constructed was the first boat that was a commercial success. Much that Fulton accomplished was undoubtedly due to the ideas he obtained from those whose experiments antedated the construction of the *Clermont*. James Rumsey began experimenting as early as 1785, and a year later John Fitch is said to have constructed the first steam-propelled craft which met with any degree of success in America. It was a most clumsy contrivance, however, being propelled by gangs of oars arranged in a frame-work at the sides. The second American steamboat was run by Fitch on the Delaware at Philadelphia in 1787. In the same year Rumsey is said to have built the third boat which operated on the Potomac. The propulsion of this novel craft was accomplished by sucking in water at the bow and expelling it at the stern—a method which has been tried in recent times. In the two following years Fitch built two other steamboats, after which Samuel Morey built a stern-wheeler, which made a trip from Hartford to New York. Fitch, who had been conducting his experiments on the Delaware at Philadelphia, came to New York where he operated the seventh American steamboat.

John Stevens began his work in steam navigation in 1791. In 1798, a steam-propelled vessel was tried on the Passaic River. The New York Legislature was petitioned by Stevens for a monopoly of steam navigation, but the petition was not granted. In 1804 a 68-foot boat, 14 feet wide, fitted with a single-screw propeller, was built by Stevens and in 1805 a twin-screw boat was launched on the North River. The machinery of this boat was afterward placed in a larger boat, the *Phoenix*, which was 103 feet 3 inches long, 16 feet wide, and 6 feet 9 inches deep. While the launching of the *Phoenix* occurred after that of the *Clermont*, if one may judge from models, the lines of Stevens' craft were much superior to those of the *Clermont*. The engine also shows greater simplicity. In the spring of 1809, the *Phoenix* made a number of trips between New York and New Brunswick,

a distance of 37 miles, in 9½ hours including stops. It was decided to sail the *Phoenix* to the Delaware River by way of the Atlantic and she left New York on June 8, 1809, arriving at Philadelphia on June 17. Thus was accomplished the first sea voyage of a steam-propelled vessel. The *Phoenix* ran as a passenger boat on the Delaware, stopping at Philadelphia, Bordentown, and Trenton. After running for a number of years over this route the *Phoenix* was wrecked at Trenton in 1814.

The original *Clermont* was built at Charles Brown's shipyard near Corlear's Hook, New York. According to a letter written by Fulton to James Watt, she was 175 feet long, had a beam of 12 feet, and a depth of 8 feet. After making four trips the length was reduced to 150 feet and the width increased to 18 feet. The propulsion was by paddle wheels, 15 feet in diameter, which were placed well forward. These were driven by a single-cylinder condensing engine of the side-lever type, which was imported from England, as the facilities in this country at that time for engine building or similar work were very poor. This engine with its driving mechanism was located amidships, and was uncovered. The cylinder was designed for a working pressure of 20 pounds.

The famous voyage of the original *Clermont* from New York to Albany began on August 17, 1807. Leaving New York at one o'clock in the afternoon, the *Clermont* arrived at the estate of Chancellor Livingston, at 10 o'clock on Tuesday, having traveled 110 miles in 24 hours at an average speed of 4.6 miles per hour. On the remaining 40 miles of the journey to Albany, this speed was increased to 5 miles per hour, making 32 hours the total time for the trip.

Steam Calorimeter. This is a device used for determining the percentage of moisture in steam. See Calorimeters.

Steam Dome. A steam dome is the dome-shaped projection on the top of steam boiler which acts as a reservoir in which the steam is comparatively dry; hence, the steam for driving an engine is obtained from the dome. The throttle valve of a locomotive is in the dome and the steam flows forward to the cylinders through a pipe inside of the boiler.

Steam Drop-Hammers. The steam drop-hammer for producing drop-forgings is commonly used in preference to the board drop-hammer for heavy drop-forging operations, especially when considerable "breaking down" or drawing is required. The capacity of steam drop-hammers, such as are used for the average drop-forging work, varies from 2000 to 5000 pounds, and, for very heavy forging operations, much larger sizes are used. A steam drop-hammer is constructed along the same general lines as a steam hammer, although there are certain variations in the

design which adapt the hammer particularly to drop-forging work. The reciprocating movement of the ram is controlled by a piston valve and the hammer is double-acting, steam being admitted above and below the piston the same as with an ordinary steam hammer. See also Drop-hammers.

Steam Engine Development. The steam engine was the result of an evolutionary development which was due to the work of several inventors. Although the most notable improvements were made by James Watt, considerable pioneer work had been done previously. In 1690 Denis Papin originated the first cylinder and piston type of steam engine, but the scheme was impracticable owing to the fact that both boiler and cylinder were combined in one vessel. Thomas Newcomen, in 1705, made a practical form of piston engine, although it was very crude and inefficient and simply provided a reciprocating motion. About 1711 Newcomen's engine was introduced for mine pumping, and by 1725 it was in common use in collieries and continued in use for about three-quarters of a century. This engine was of the atmospheric type, depending for its action upon condensation of steam and the atmospheric pressure.

In 1763, James Watt, an instrument maker in Glasgow, while repairing a model of Newcomen's engine, perceived the waste of steam resulting from alternate chilling and heating of the cylinder. The result was the origin of the condensing apparatus, involving the use of a separate condenser, cooling water, and an air pump for maintaining a partial vacuum. Although this was a notable improvement, the engine was still suitable only for pumping, as it was a single-acting type with steam admitted during the entire stroke. Motion was transmitted from the piston to the pump rod through an oscillating "walking beam," but there was no rotary motion. In a second patent, issued in 1781, the sun and planet wheels and other methods of securing a continuous rotary motion are described. Watt had invented the crank and connecting-rod for this purpose, but meanwhile it had been patented by Pickard; hence, the sun and planet motion was used by Watt until the patent on the crank expired. In 1782, Watt patented two additional improvements of great importance. One was the double-action principle, whereby pressure is applied alternately to each side of the piston, and the other was in using steam expansively by stopping its admission when the piston had made only part of its stroke. Henry Maudslay made further improvements in the steam engine by eliminating the cumbersome wooden walking beam of the Newcomen and Watt engines, and connecting the cross-head and crank direct.

Steam Engine Horsepower Rating. The capacity or power of a steam engine is rated in horsepower, one horsepower (H.P.)

being the equivalent of 33,000 foot-pounds of work done per minute. The horsepower of a given engine may be computed by the following formula in which P = mean effective pressure per square inch; L = length of stroke, in feet; A = area of piston, in square inches; N = number of strokes per minute = number of revolutions $\times$ 2.

$$\text{H.P.} = \frac{PLAN}{33{,}000}.$$

The derivation of this formula is explained, as follows: The area of the piston, in square inches, multiplied by the mean effective pressure, in pounds per square inch, gives the total force acting on the piston, in pounds. The length of stroke, in feet, times the number of strokes per minute gives the distance the piston moves through in feet per minute. The pressure in pounds multiplied by the distance moved through in feet gives the foot-pounds of work done. Hence, $P \times L \times A \times N$ gives the foot-pounds of work done per minute by a steam engine. If one horsepower is represented by 33,000 foot-pounds per minute, the power or rating of the engine will be obtained by dividing the total foot-pounds of work done per minute by 33,000.

Steam Flow. See Darcy's Formula; also Napier Formula.

Steam Flow Meter. See Flow Meter.

Steam Metal. Alloys suitable for steam valves and other purposes where the metal is exposed to the action of the steam are often known as "steam metals." Alloys of copper and zinc are unsuitable for this purpose, because their strength is materially reduced at high temperatures and the metal deteriorates by continued heating and cooling. Alloys of copper with from 10 to 12 per cent of tin are, therefore, used for this purpose. A good composition consists of 88 per cent of copper, 10 per cent of tin, and 2 per cent of zinc. This alloy has a tensile strength of about 33,000 pounds per square inch, when cold, and over 30,000 pounds per square inch, when heated to 400 degrees F.

Steam Pipe Vibration. See Vibration Due to Steam Flow.

Steam Separators. Steam separators are used in steam power plants in order to intercept the moisture in the steam and the water of condensation that flows along with it, before the steam reaches the engine cylinders or turbines, thus protecting them from damage by water. It is a well-known fact that steam engines and turbines operate more economically and at higher efficiency when supplied with dry steam than when supplied with moisture-laden steam. For this reason, a steam separator will

effect a saving in fuel and also a considerable saving in oil and engine repairs.

Steam Tables. Steam tables may be found in many engineering handbooks, and in the catalogues of various kinds of steam apparatus. They give useful data relating to steam at different pressures, and include such factors as: 1. pressure; 2. temperature; 3. heat in water above 32 degrees F.; 4. internal latent heat; 5. external latent heat; 6. latent heat of evaporation; 7. total heat of evaporation; 8. weight of a cubic foot of steam, in pounds; 9. volume of a pound of steam, in cubic feet.

Steam Turbine. See Turbine, Steam.

Steatite. Same as Talc.

Steel Abrasives. Steel abrasives are small globules or particles of steel made by a method that gives them unusual hardness and toughness. These abrasives are used in a process similar to that of sand-blasting, the difference being that the abrasive action is from the steel particles instead of using sand.

Steel abrasives are first made into round globules or shot by a blowing process. Each globule, after being blown to shape, is quenched, the rapid chilling giving it a very close dense structure. A subsequent heat-treatment reduces the chilling strains set up by the quenching, so that the shot or abrasive will resist impact and wear in a satisfactory manner.

Chilled shot, being round, is used when work can be cleaned by shock. The round globules act like numerous ball-peen hammers. The peening action gives satisfactory results in cleaning rough work, the surface of which is not intended for subsequent enameling, galvanizing or plating. For work which is to be subsequently treated by any one of the processes just mentioned, what is known as angular steel grit is used. Angular grit is chilled shot broken down to produce sharp angular corners. The angular grit retains the original physical properties of hardness and toughness, but in blasting operations it has the advantage of producing both impact and actual cutting action. It cuts like numerous sharp tools, actually removing minute chips from the surface being blasted and producing a matte finished appearance. The coarseness or fineness of the surface can be controlled by the size of the angular grit used. The fact that steel abrasive actually cuts, makes possible much more rapid production than with sand.

The crushing of shot to make angular grit is an expensive operation due to the rapid wear of the crushing tools. It is also impossible to control the sizes in the crushing except in a very limited way, and a certain loss, therefore, results from pulveriz-

ing part of the crushed material into small unsalable sizes. This loss, together with the actual cost of the crushing operation, makes the cost of angular grit somewhat higher than of globular shot. This, however, is offset by its capacity for faster blasting production and cleaner work.

Steel abrasive, either in the form of shot or angular grit, can be used over and over again hundreds of times. It is superior to sand in that it does not break down like sand does, and one ton of steel abrasive will do the work of a carload of the very best sand-blast sand. In general, the relative ultimate cost, based on work produced by steel abrasive as compared with sand-blast sand, is only about from one-quarter to one-half of the latter.

The nozzles of the blast also last from two to four times longer with steel abrasives than with sand. The slower wear of the orifice also effects a big saving in compressed air. The dust due to ordinary sand-blasting is practically absent, as there is no dust from the metal abrasives themselves. Much storage space is saved as compared with that needed for sand, and the handling charge is very much reduced.

Steel Castings. Steel castings may be defined as unforged and unrolled castings made of Bessemer, open-hearth, crucible or electric-furnace steel. Steel castings are especially adapted for machine parts that must withstand shocks or heavy loads. They are stronger than either wrought iron, cast iron, or malleable iron and are very tough. Steel for comparatively small castings may be made by the Bessemer or crucible furnaces, whereas for large castings, the open-hearth furnace is preferable. The electric furnace is now used considerably, some of the larger sizes being employed in conjunction with open-hearth furnaces and Bessemer converters which partially refine the charge.

There are two very general classes of steel castings—namely, the carbon steel and the alloy steel. The carbon steel castings may have a carbon content ranging from 0.05 to 1.70; manganese, from 0.50 to 1.00; silicon, from 0.20 to 0.75; phosphorus, 0.05 maximum; and sulphur, 0.06 maximum. Low-carbon steels (containing less than 0.20 per cent carbon) may have a tensile strength ranging from 40,000 to 70,000 pounds per square inch. High-carbon steels containing more than 0.40 per cent carbon may have a tensile strength ranging from 70,000 to 120,000 pounds per square inch. The medium-carbon cast steels with a carbon content varying from 0.20 to 0.40 may have a tensile strength varying from 60,000 to 80,000 pounds per square inch. Alloy cast steels contain special elements, such as chromium, nickel, molybdenum, tungsten, etc. These various alloys, in conjunction with suitable heat-treatments, make it possible to secure steel castings having a wide range of physical properties.

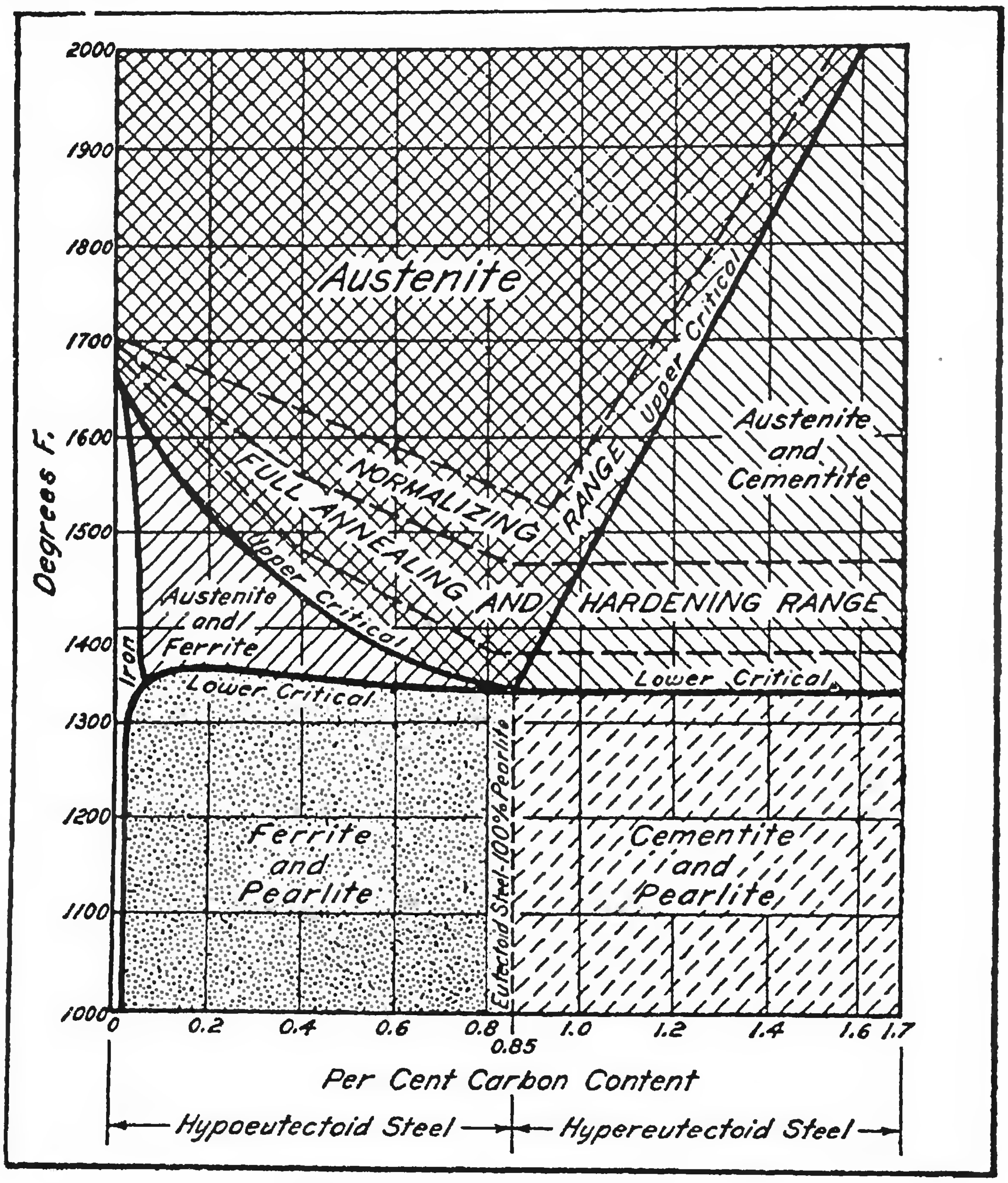
Steel Coloring. A method of bluing iron and steel, in order to obtain pleasing color effects, known as the *niter process*, consists in melting niter or nitrate of potash, also called "saltpeter," in an iron pot at a temperature of about 600 degrees F. The parts to be blued are cleaned and polished and immersed in the molten nitrate of potash until a uniform color of the desired shade has been obtained. This requires only a few seconds. The articles are then removed, allowed to cool, and the adhering niter washed off in water. If there is no danger of warping, the parts may be immersed in the water immediately after having been removed from the nitrate-of-potash bath. The articles are then dried in sawdust, and linseed oil is applied to prevent rusting. To secure uniform colors, a pyrometer should be used to gage the temperature of the nitrate-of-potash bath, because high heats will produce darker colors, whereas lower heats will give lighter shades.

Brown Finish: The following formula is for browning gun barrels and similar steel articles: Alcohol, 1½ ounces; tincture of iron, 1½ ounces; corrosive sublimate, 1½ ounces; sweet spirits of niter, 1½ ounces; blue vitriol, 1 ounce; nitric acid, ¾ ounce; and warm water, 1 quart. Dissolve the above ingredients in the water and keep in a glass bottle. The gun barrel to be treated is cleaned with potash of soda to remove the grease, and all stains are then removed with fine emery cloth, so that an even bright surface is produced. The bore and vent of the barrel are closed by plugs of wood. The solution is then applied to the surface of the steel with a sponge and allowed to dry in the air for 24 hours, after which the loose rust is rubbed off with a steel scratch brush. Another coating of the solution is now applied, and allowed to dry in the same manner, after which the scale is again rubbed off with a scratch brush. Finally the barrel is washed in boiling water, dried rapidly, and wiped with boiled linseed oil or given a coat of shellac. See also Gun-metal Finish on Steel.

Steel, Constituents or Structure. In carbon steel that has been fully annealed, there are normally present, apart from such impurities as phosphorus and sulphur, two constituents: the element iron in a form metallurgically known as *ferrite* and the chemical compound iron carbide in the form metallurgically known as *cementite.* This latter constituent consists of 6.67 per cent carbon and 93.33 per cent iron. A certain proportion of these two constituents will be present as a mechanical mixture. This mechanical mixture, the amount of which depends on the carbon content of the steel, consists of alternate bands or layers of ferrite and cementite. Under the microscope it frequently has the appearance of mother-of-pearl and hence has been named *pearlite.* Pearlite contains about 0.85 per cent carbon and 99.15 per cent

iron, neglecting impurities. A fully annealed steel containing 0.85 per cent carbon would consist entirely of pearlite. Such a steel is known as *eutectoid* steel and has a laminated structure characteristic of an eutectic alloy. Steel which has less than 0.85 per cent carbon (*hypo-eutectoid* steel) has an excess of ferrite above that required to mix with the cementite present to form pearlite, hence both ferrite and pearlite are present in the fully annealed state. Steel having a carbon content greater than 0.85 per cent (*hyper-eutectoid* steel) has an excess of cementite over that required to mix with the ferrite, hence both cementite and pearlite are present in the fully annealed state. The structural constitution of carbon steel in terms of ferrite, pearlite, cementite and austenite for different carbon contents and at different temperatures is shown by the accompanying diagram.

Effect of Heating Fully Annealed Carbon Steel: When carbon steel in the fully annealed state is heated above the lower critical



Iron-Carbon Phase Diagram

point, which is some temperature in the range of 1335 to 1355 degrees F. (depending upon the carbon content), the alternate bands or layers of ferrite and cementite which make up the pearlite begin to merge into each other. This process continues until the pearlite is thoroughly "dissolved," forming what is known as *austenite.* If the temperature of the steel continues to rise and there is present, in addition to the pearlite, any excess ferrite or cementite, this also will begin to dissolve into the austenite until finally only austenite will be present. The temperature at which the excess ferrite or cementite is completely dissolved in the austenite is called the *upper critical point.* This temperature varies with the carbon content of the steel much more widely than the lower critical point (see diagram).

Effect of Slow Cooling Carbon Steel: If carbon steel which has been heated to the point where it consists entirely of austenite is slowly cooled, the process of transformation which took place during the heating will be reversed but the upper and lower critical points will occur at somewhat lower temperatures than they do on heating. Assuming that the steel was originally fully annealed, its structure upon returning to atmospheric temperature after slow cooling will be the same as before in terms of the proportions of ferrite or cementite and pearlite present. The austenite will have entirely disappeared.

Effect of Rapid Cooling or Quenching Carbon Steel: Observations have shown that as the rate at which carbon steel is cooled from an austenitic state is increased, the temperature at which the austenite begins to change into pearlite drops more and more below the slow cooling transformation temperature of about 1300 degrees F. (For example, a 0.80 per cent carbon steel that is cooled at such a rate that the temperature drops 500 degrees in one second will show transformation of austenite beginning at 930 degrees F.) As the cooling rate is increased, the laminations of the pearlite formed by the transformation of the austenite become finer and finer up to the point where they cannot be detected under a high power microscope, while the steel itself increases in hardness and tensile strength. As the rate of cooling is still further increased, this transformation temperature suddenly drops down to around 500 degrees F. or lower depending upon the carbon content of the steel. The cooling rate at which this sudden drop in transformation temperature takes place is called the *critical cooling rate.* When a piece of carbon steel is quenched at this rate or faster, a new structure is formed. The austenite is transformed into *martensite* which is characterized by an angular needlelike structure and a very high hardness.

If carbon steel is subjected to a severe quench or to extremely rapid cooling, a small percentage of the austenite, instead of

being transformed into martensite during the quenching operation, may be retained. Over a period of time, however, this remaining austenite tends to be gradually transformed into martensite even though the steel is not subjected to further heating or cooling. Such martensite has a lower density than austenite, such a change or "aging" as it is called, often results in an appreciable increase in volume or "growth" and the setting up of new internal stresses in the steel.

Steel, Copperized. Tests made by a committee of the American Society for Testing Materials with the cooperation of the United States Bureau of Standards, together with other data available, prove that by alloying from 0.15 to 0.25 per cent copper with normal open-hearth or Bessemer steel, the rate of corrosion of steel is very much reduced, where the products are exposed to alternate attacks of air and moisture. Two heats of basic open-hearth steel were copperized in varying amounts from about 0.01 per cent up to 0.25 per cent. Sheets from different ingots were made and exposed to the weather for various lengths of time. The tests proved that very low amounts of copper in steel tend to lower the corrosion rate. Copper, to the extent of 0.12 per cent, is said to be sufficient to neutralize the influence of sulphur amounting to 0.055 per cent. Copper amounting to 0.15 per cent is sufficient to protect steels even if the sulphur content is much higher than normal.

Steel, Hot-Pressed. See Hot-pressed Steel Parts.

Steel, Classes. See kind of steel or process: Air-hardening Steel; Carbon Steel; Chromium-vanadium Steel; Cobaltcrom-Steel; Crucible Steel; Electric Steel; High-speed Steel; Manganese Steel; Molybdenum Steel; Natural Alloy Steel; Nickel-chromium Steel; Nickel Steel; Spring Steels; Stainless Steel; Titanium Steel; Tungsten Steel; Tool Steel; Vanadium Steel; Bessemer Process; Open-hearth Process; Gear Steels; Drop-forging Steel.

Steel Rule Dies. These are short-run dies made with steel cutting rules which act as knives to shear blanks from fibrous and other nonmetallic materials. The steel rules are obtainable from printers' supply houses and are normally used in the printing of straight lines in letterpress printing. The material against which the steel rule shears is usually brass, copper, fiber, wood or steel.

One manufacturer of electrical fuse boxes, meter mounts, etc. is using a method of designing and employing steel rule dies that cause them to rival conventional dies in accuracy and life. This manufacturer has been able to obtain runs of 200,000 pieces with a remaining die life for about another 200,000 pieces. In

this method the punch, sawed out of plate, is usually the bottom member. The die consists of a high-density plywood matrix, called a "surround," which is slotted to accept various configurations of steel rule. The wooden surround is backed by a steel member of light plate. The rule segments butt on this plate, with the rule edges standing out from the face of the wood to a height based on job requirements. Depending on the type of stock being blanked and the anticipated number of pieces, sections of various kinds of stripper materials are fastened next to the rules. For short to medium runs, resilient neoprene rubber is used. For longer runs, steel strips, backed by springs, force the blank out of the die.

Steels, Normal and Abnormal. The terms "normal" and "abnormal" are generally used to differentiate between a steel that will harden 100 per cent hard and a steel that will have soft spots after hardening in the ordinary way, without the use of cyanide or salt baths. It has been demonstrated that it is often possible to harden an abnormal steel 100 per cent hard by the use of cyanide or salt baths.

Steels, Production. All commercial iron or steel contains iron as the chief constituent, but the percentages of carbon and other elements and the methods by which iron or steel are produced, as well as the processes to which they may be subjected, so change the characteristic properties that there are many distinct forms of iron and steel, some of which have properties so different as to appear like different metals. Pig iron is the product into which the iron ore is first converted in a blast furnace. From pig iron, all commercial irons and steels are made. Wrought iron is produced by what is known as the "puddling" process. It contains a lower percentage of carbon than other forms of iron and steel, and is fibrous, ductile, and malleable. When heated, it can be formed and shaped readily by forging, and can easily be welded. Bessemer steel is made from pig iron in a Bessemer converter; hence, its name. Open-hearth steel is produced from pig iron in a so-called "regenerative" furnace, the hearth of which is exposed to the action of the flame. Steel made by both the Bessemer process and the open-hearth process is used for rails, and also for structural iron shapes. It is also often known as "mild steel" or "machine steel." When steel contains enough carbon to permit hardening and tempering, it is known as tool steel. Such steels are made in an electric furnace or by the crucible process, excepting the lower grades which are made by the open-hearth process. Alloy steels may be made by any of the processes mentioned, by adding other metals, such as chromium, nickel, tungsten, etc. Cast iron is generally produced

from pig iron in what is known as a "cupola" furnace. It contains a larger propo tion of carbon than any of the other forms of iron or steel and s easily cast in molds, but is neither ductile nor malleable. Stee castings are made from steel, generally melted in an open-hearth furnace, electric furnace, or a small Bessemer converter; crucible steel castings are also made. At one time, there was quite a distinct line of demarcation between wrought iron and steel, but now these are distinguished mainly by their physical characteristics, wrought iron having a fibrous structure, while steel has more of a grain or crystalline structure.

Bessemer and Open-hearth Steels: Most of the steel used at the present time for structural purposes is made by the open-hearth process. The tonnages of the Bessemer and open-hearth processes were about equal in the United States in 1907, but in 1912 the open-hearth furnace produced approximately twice as much steel as the Bessemer converter and since then the open-hearth process has been gaining steadily and now a large percentage of the total tonnage is made by the open-hearth process. Better grades of structural steel are made in the open-hearth furnace, and the process produces a more uniform and reliable steel than the Bessemer, as the operations are under better control. For additional information on steel-making refer to the different processes mentioned.

Steel-making by Direct Process: The larger portion of the steel-making pig iron is transported in molten condition from the blast furnace to the steel mill and is never marketed in the form of pig iron at all. Similarly, during the initial stages of rolling steel products, the ingots, blooms, and slabs are merely intermediate stages in the production of steel and not ordinarily commercial products. Thus, before the ingot has lost the heat acquired in producing the steel itself, it has been rolled into a bloom, a slab, or a billet and is ready to be rolled into some finished rolled product, such as rails, plates, or structural shapes. This saving of heat and the use of automatic machinery in handling these heavy rolled products keep down the fuel and labor costs; therefore, the prices of the heavy products are largely controlled by the cost of the crude steel. But in the case of light-rolled products, such as wire rods and sheets, more rolling is required, with a corresponding loss of heat and greater use of hand labor; therefore, the prices of light-rolled products are largely influenced by the fuel and labor costs.

Steels, Strength. The strength of iron and steel varies considerably according to the quality of the material and the treatment to which it has been subjected. Both mechanical working and heat-treatment have a decided effect on the strength of steel;

hence, the strength figures which follow are given only as a general guide.

Bessemer and open-hearth mild steels have a tensile strength of about 60,000 pounds per square inch, and a compressive strength of practically the same value, with a modulus of elasticity of 29,000,000. This class of steel is that used as structural steel for beams, etc., or as boiler steel for plates. The strength of alloy steels varies over a wide range, according to their composition and heat-treatment. The tensile strength of a low-carbon 3½ per cent heat-treated nickel steel may vary from 75,000 to 150,000 pounds per square inch, depending upon the drawing temperature. Some nickel-chromium steels vary in tensile strength from 120,000 to 220,000 pounds per square inch owing to different heat-treatments, and alloy steels in general commonly have tensile strength variations ranging from 100,000 to 200,000 pounds per square inch.

Steel wire varies in strength according to its condition and quality. Annealed steel wire has a tensile strength of 80,000 pounds per square inch; unannealed steel wire, 120,000 pounds per square inch; crucible wire, 180,000 pounds per square inch; suspension-bridge wire, 200,000 pounds per square inch; plow-steel wire, 270,000 pounds per square inch; and piano wire, 300,000 pounds per square inch. Since wire is made in small sizes only, these high values for strength per square inch would not apply to a bar actually having an area of one inch square.

Effect of Mechanical Working: The strength of a steel depends upon mechanical working as well as upon its chemical composition. A plate 2 inches thick is not as strong and tough, proportionately, as a plate ¼ inch thick, because the thinner plate is much more thoroughly worked. Excessive working, on the other hand, lessens the ductility. For instance, the strength of a steel may be about doubled by drawing it into wire, but the ductility will be reduced to a very small fraction of 1 per cent. When steel is "cold drawn" or "cold rolled," as the process is frequently, although erroneously, called, its tensile strength may be increased as much as from 20 to 40 per cent and its elastic limit from 60 to 100 per cent; but its elongation is reduced. By this process the steel is given a hard skin or shell, but the core is unchanged. If the steel contains a large proportion of carbon, the manner of cooling after working will also have a very important effect. Sudden cooling or "hardening" has an effect similar to that of cold working. Steel worked at a blue or black heat is injured more than if strained when cold. This property is known as *blue shortness.*

Effect of Temperature: Varying temperatures have a decided effect upon the strength of iron and steel. Intense cold raises

the limit of elasticity of both iron and steel, but does not affect their tensile strength. It reduces their resistance to impact, however. With a rising temperature from that of the normal temperature of 70 degrees F., there is first an increase in strength and then a rapid drop. Tests have been made to determine the strength of iron and steel at high temperatures. The results show that as the temperature is increased, steel, wrought iron, and cast iron grow stronger up to a certain point. According to one test, the maximum strength of wrought iron is reached at 450 degrees F., and the corresponding temperature for steel is 525 degrees F. With further increase in temperature, both the ultimate and elastic strength decrease rapidly. According to another test, structural steel has a strength of 132 per cent at 400 degrees F., 122 per cent at 570 degrees F., 86 per cent at 750 degrees F., and 28 per cent at 1100 degrees F. Cast steel has its highest value of strength of 125 per cent at 400 degrees F., which is reduced to 121 per cent at 570 degrees F., to 97 per cent at 750 degrees F., and to 57 per cent at 930 degrees F. These figures are, of course, subject to variation, but are given in order to indicate the probable weakening of various irons and steels with increasing temperatures.

Steel Wire Gage. This gage is used in the United States for all bare wire of galvanized and annealed steel and iron, and also for all tinned and spring steel wire. It is also known as the United States Steel Wire Gage, Washburn & Moen Wire Gage, American Steel & Wire Co.'s Gage, Roebling Wire Gage, and National Wire Gage. Steel Wire Gage tables may be found in Engineering Handbooks.

Steel Wool. Steel wool is made by shaving thin layers of steel from wire. The wire is pulled, by special machinery built for the purpose, past cutting tools or through cutting dies which shave off chips from the outside. Steel wool consists of long, relatively strong, and resilient steel shavings having sharp edges. This characteristic renders it an excellent abrasive. The fact that the cutting characteristics of steel wool vary with the size of the fiber, which is readily controlled in manufacture, has adapted it to many applications.

Metals other than steel have been made into wool by the same processes as steel, and when so manufactured have the same general characteristics. Thus wool has been made from copper, lead, aluminum, bronze, brass, monel metal, and nickel. The wire from which steel wool is made may be produced by either the Bessemer, or the basic or acid open-hearth processes. It should contain from 0.10 to 0.20 per cent carbon; from 0.50 to 1.00 per cent manganese; from 0.020 to 0.090 per cent sulphur; from 0.050 to

0.120 per cent phosphorus; and from 0.001 to 0.010 per cent silicon. When drawn on a standard tensile-strength testing machine, a sample of the steel should show an ultimate strength of not less than 120,000 pounds per square inch.

Stellite. Haynes Stellite is an alloy of cobalt, chromium and tungsten and is non-ferrous or without iron in its composition. The hardness of this alloy is not materially affected by heat up to 1500 degrees F. and it is actually tougher at red heat than when cold. This important characteristic explains its wide application as a cutting tool material. Haynes Stellite works best when operated at high speed and with a comparatively light feed. The resistance of Stellite to shocks adapts it to interrupted cuts.

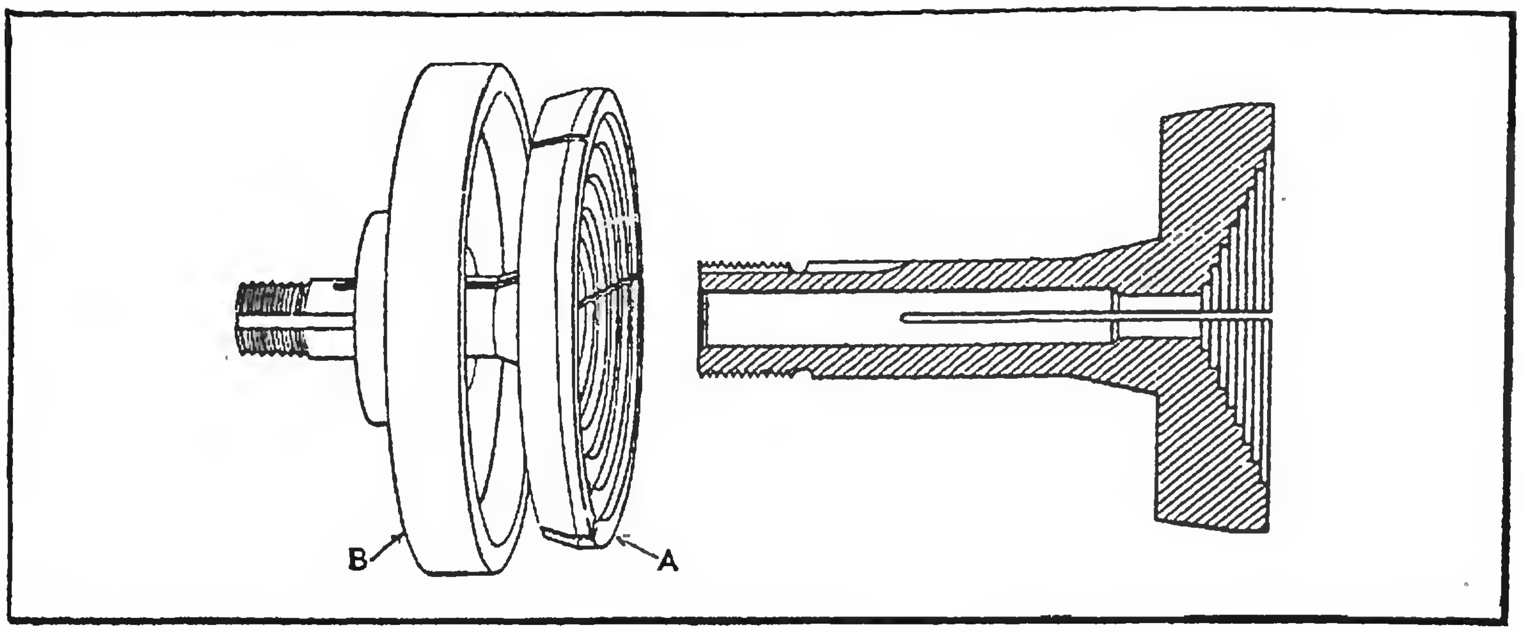
J-Metal: The cutting tool material known as J-Metal is an improved grade of Haynes Stellite. The use of J-Metal results either in higher cutting speeds or in greater production between tool grindings. J-Metal is adapted to various classes of machining operations on practically all kinds of machinable materials, excepting chilled cast iron and manganese steel. The hardness of J-Metal at room temperature is 600 Brinell or Rockwell C, 60-62. It is important to note that the hardness of J-Metal is practically unaffected at red heat and this red hardness is considerably greater than that of high-speed steel.

Haynes Stellite—2400: This is another cobalt-chromium-tungsten alloy. Cutting tools made of this material have greater edge strength and longer economic tool life at even higher speeds than tools made of J-Metal, without reduction of feed or depth of cut. In fact, the speeds and feeds recommended are from 10 to 50 per cent greater than those for J-Metal. This alloy may be used for roughing or finishing cast and forged steels, cast and malleable irons, nitrided, stainless and other alloy steels.

Step Bolt. A step bolt is a bolt similar to a carriage bolt, except that the head is much flatter, although of spherical form.

Step-Chuck. The step- or "wheel" chuck is a form having a series of annular recesses or steps of various diameters, for holding work which must be located very accurately with reference to its periphery. These chucks are used for work of larger diameters than could be held in a collet chuck. The part *A* (see illustration) is the chuck proper, and the outer member *B* is known as the *closer,* because it serves to close in the chuck as the latter is drawn back by the drawback spindle of the lathe.

Stephenson Link Motion. The general arrangement of the Stephenson link motion for operating engine valves is shown by the accompanying diagram. The principal parts are the eccentrics *F* and *B*; the eccentric rods *R*; and the link *L*. Each eccentric is surrounded by an eccentric strap which is free to



Step-chuck and Closer

revolve so that, as the eccentrics rotate, they act the same as cranks and impart a reciprocating motion to the slide valve enclosed in the steam chest. Two eccentrics are necessary, if the engine must run either forward or backward. By means of the reversing lever *A*, the end of the forward motion eccentric rod can be placed opposite the valve rod connection and then the motion of the valve will be derived from the forward eccentric. Similarly, when the link *L* is shifted by means of the reversing lever and its connections, the backward motion eccentric actuates the valve, and the direction of movement is reversed. When the link is either all the way down or up as far as it will go, the valve is given the maximum travel, and, as the link is shifted toward the central or neutral position, the travel gradually decreases. This feature is taken advantage of in the running of locomotives, in order to secure greater economy in the use of steam.

Sterilkote. A synthetic coating for metals that is sufficiently adherent and elastic to permit bending, drawing, and other press

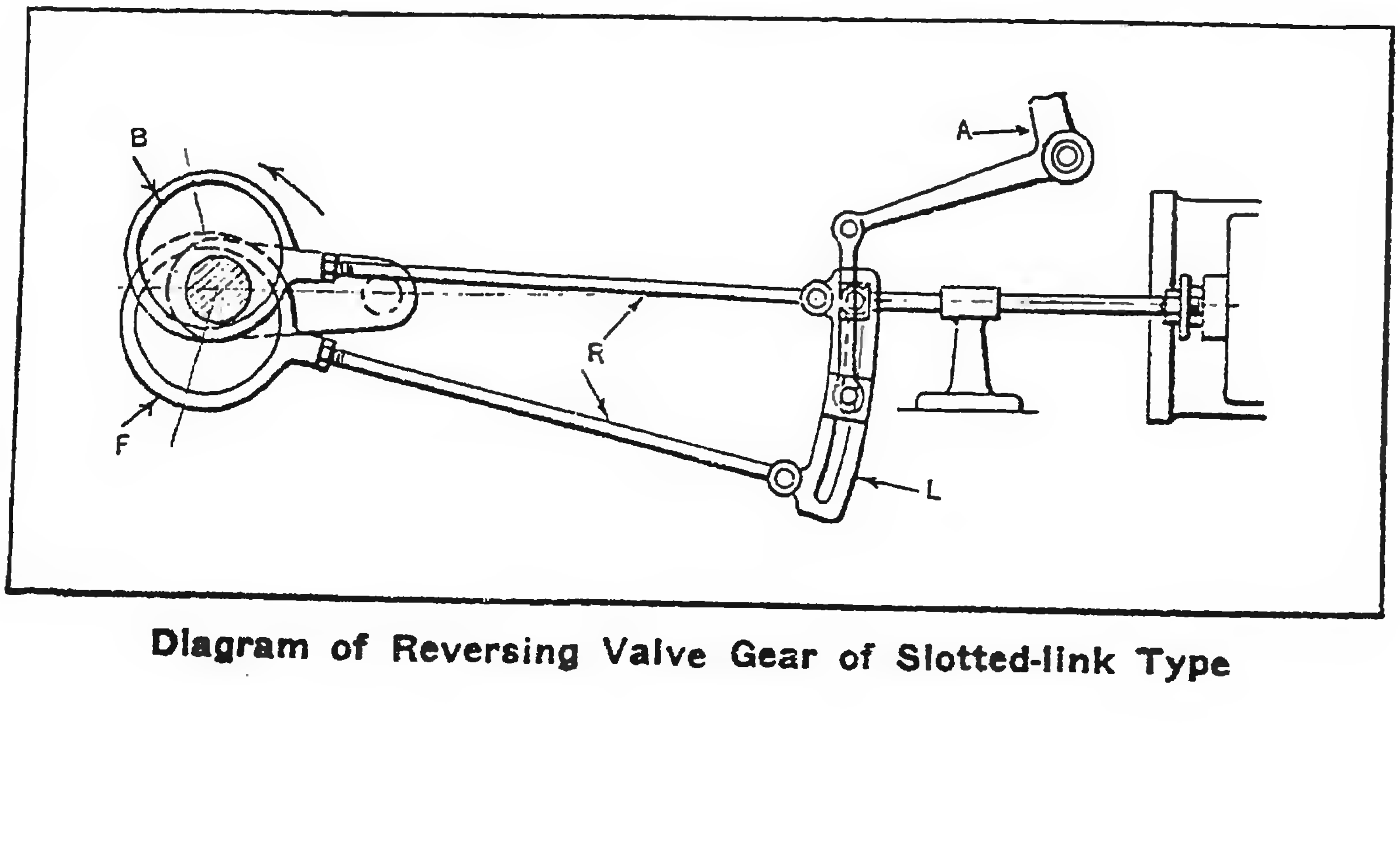


Diagram of Reversing Valve Gear of Slotted-link Type

operations without marring the finish. Applied to metal by spraying or "roller-coating" and then baked. Recommended as a lining for beverage and food conveyors, since it is odorless, tasteless, and non-porous. Also recommended for metal surfaces subjected to hard usage such as washing-machine lids, dispensing cabinets, and laboratory equipment.

Sterro Metal. Sterro metal is the name formerly used for an alloy consisting of about three parts of copper to two parts of zinc, with small percentages of iron and tin. This alloy is generally known as "Delta metal."

Stiefel Process. In the Stiefel process of producing seamless tubes a heated billet is passed between the faces of two parallel disks which impart to it a rotary and a forward motion, thereby forcing the billet over and against a piercing mandrel. The working faces of the disks are shaped in such a manner as to cause a uniform speed of rotation, so that the parallel longitudinal arrangement of the fibers is not disturbed.

Stiffness. Stiffness is a measure of the degree of resistance to deflection or bending resulting from a load applied to a part, and is dependent on the strength and elasticity of the material and the dimensions of the part.

Stocking Cutters. Roughing cutters which are intended primarily for removing surplus stock are sometimes classed as "stocking cutters." For example, when the pitch of a gear is large enough to warrant taking both roughing and finishing cuts, a "stocking cutter" may be used for removing the bulk of the metal, leaving a small amount on the sides of the teeth for finishing. Several different types of stocking or roughing cutters are in use.

Stone-Sawing Strand. For sawing blocks of sandstone, limestone, or similar soft stone, a wire strand made by twisting three wires together is used. The sand-sawing strands should not be used for sawing marble or granite, as they are not suitable for these harder stones. The strands are made in five different sizes, varying from 1/8 to about 7/32 inch in diameter, the approximate gage of the wires used varying from No. 16 to No. 12 steel wire gage.

Stone's English Gear Bronze. This bronze is very serviceable for gears and worm-wheels. It is composed of 89 per cent of copper and 11 per cent of tin. This bronze is very serviceable for gears and worm-wheels, where the requirements are severe, and especially when quiet running is an important feature. The gear made from this bronze should run with well-finished high-carbon or alloy steel gears. See also Phosphor-bronze.

Stop Mechanism, "Beaver-Tail." See "Beaver-tail" Stop.

Stop-Pins for Dies. The stop-pin on a die is a device for controlling the position of the stock as it is fed through for each successive stroke of the press, so that the spacing of the openings cut into the stock will be uniform and a predetermined distance apart. There are many different types of stop-pins, such as the plain fixed stop-pin, the bridge stop-pin, the simple latch, the spring toe latch, the side swing latch, the positive heel-and-toe latch, etc. These devices, with the exception of the first, can be used with either hand feed or automatic roll feed.

Storage Batteries. Secondary or storage batteries are devices which transform chemical into electrical energy which can be restored again after having been consumed. The unit of the battery is the cell, that is, a jar or retainer containing positive and negative plates (*electrodes*) and a conductive liquid (*electrolyte*). The voltage of a cell depends upon the electro-chemical properties of the materials used for electrodes and electrolyte, and is independent of the size of the electrodes or the quantity of the electrolyte; the current capacity of a cell is dependent upon the surface of the electrodes submerged in the electrolyte. Several cells together form a *battery.* When after a discharge an external source of electrical energy is connected to the battery, and current is forced through it in the direction opposite to that taken by the discharge current, the electro-chemical process of the discharge is reversed and the battery is gradually brought back to the same condition it was in when the discharge started. This process is called *charging* the battery. The input during charge must be somewhat greater than the output required at discharge, on account of various internal losses and on account of polarization. The rate of discharge of a storage battery is the *number of amperes* that it will supply continuously for a given time. All charging should be done at the rates given by the manufacturer. Only direct current can be used to charge storage batteries.

Lead-Acid Batteries: This type of storage battery is commonly used in automobiles, railway train lighting and air conditioning, and for emergency standby purposes. The cathode is of lead peroxide and the anode is of sponge lead with a dilute solution of sulphuric acid as an electrolyte. The so-called *Plante* type of battery has a pure lead plate of large area, while the *pasted-plate* type has grids of cast lead-antimony alloy with the active material applied in the form of a paste. This latter type is the most widely used.

Alkaline Battery: This type of storage battery, also called the Edison storage battery, is commonly used for railway signal systems, electric industrial trucks and tractors, police and fire

alarm systems, and other applications where dependability together with long service life is important. One electrode consists of a nickel-plated steel grid with perforated tubes of similar material containing the active material nickel oxide. The other electrode is of similar construction, except that pockets are used instead of tubes and these contain black oxide of iron. The electrolyte is a solution of potassium and lithium hydroxide in water.

Storage Battery Ratings. The following S.A.E. standard specifications are applied only to lead-acid storage batteries for automotive purposes.

Batteries for combined starting and lighting service shall have two ratings. The first rating shall indicate the lighting ability and shall be the capacity in ampere hours of the battery when it is discharged continuously to an average final terminal voltage equivalent to 1.75 per cell at the 20-hour rate for passenger car and motor truck service, and at the 4-hour rate for motorcoach service. The temperature of the battery at the beginning of such discharge shall be exactly 80 degrees F., and an average temperature of 80 degrees F. shall be maintained during discharge with a maximum variation of $\pm$ 5 degrees F. The second rating shall apply only to batteries used in passenger car and motor truck starting and lighting service. This rating shall indicate the cranking ability of the battery at low temperatures and shall be (1) the time in minutes when the battery is discharged continuously at 300 amperes to a final average terminal voltage equivalent to 1.0 volt per cell, the temperature of the battery at the beginning of such discharge being zero degrees F.; and (2) the terminal battery voltage 5 seconds after beginning such discharge.

Stove Bolt. This bolt has been so named because of its use in stove building. It is made in a number of different forms, either with a round button, or flat countersunk head, the head having a slot for a screwdriver and the threaded end being provided with a square or hexagon nut.

Stove Coal. This coal is in pieces of such size that they will not pass a screen of 1⅜-inch mesh, but will pass a screen of 2-inch mesh.

Straddle Milling. When it is necessary to mill opposite sides of duplicate parts so that the surfaces will be parallel, two cutters can often be used simultaneously. This is referred to as *straddle milling*. The two cutters which form the straddle mill are mounted on one arbor, and they are held the right distance apart by one or more collars and washers. Side-mills which have teeth on the sides, as well as on the periphery, are used for work of this kind.

Straightedges. Straightedges are used to test flat surfaces for determining whether or not they are true planes, and also for testing round parts for bends, or curvatures in a lengthwise direction. A common form of machinists' straightedge is of rectangular section. In order to increase the sensitiveness of a straightedge for showing minute deviations or curvatures, the testing edge is made narrower by beveling one side, thus decreasing the width to about 1/16 inch. For work requiring extreme accuracy, the type known as a *knife-edge* straightedge is used. The testing edge is very narrow and is of semicircular cross-section so that a line contact is obtained instead of a surface contact, as with the form having flat edges. This line contact shows any minute curvature which may exist, and as the edge is curved, the accuracy of the test will not be affected if the straightedge is not held exactly at right angles to the surface being tested.

Straight-Line Motions. A combination of links arranged to impart a rectilinear motion to a rod or other part independently of guides or ways is known either as a *straight-line* motion or a *parallel* motion, the former term being more appropriate. Mechanisms of this type were used on steam engines and pumps of early designs to guide the piston-rods, because machine tools had not been developed for planing accurate guides. The principal application of straight-line motions at the present time is on steam engine indicators for imparting a rectilinear movement to the pencil or tracing point. Very few straight-line mechanisms produce a motion which is absolutely straight, and the general practice is to so design them that the guided part will be on the line when at the center and extreme ends of the stroke.

Straight-Sided Power Presses. Presses of this type have neither a gap nor arch in the frame but, as the name implies, have a straight-sided frame. This style is suitable for heavy blanking, piercing, forming, redrawing, reducing, and bending. This type of press was originally designed for trimming drop-forgings while either hot or cold. What are known as *straight-sided trimming presses* are equipped with side cut-off attachments consisting of an outer slide operated by a pitman connecting with a crank at the outer end of the main crankshaft. This outer slide may be used either for punching holes or for cutting off and trimming. Embossing is often done on straight-sided presses. The term "straight-sided" also implies that the press has a single crank.

Strain. Strain is a measure of the change in size or shape of a body referred to its original size or shape. It is sometimes expressed as the change per unit of linear dimension (in inches

per inch of length or per cent of length). In tension tests, it is usual to measure only one component of strain and to refer to this as the "strain." In such cases, the linear strain is the elongation or change in length of the specimen obtained by dividing the increase in gage length of the specimen by the original gage length.

Strain Hardening. Same as Work Hardening.

Strain Theory, Maximum. See under Stress Theories.

Stranded Conductor. In electricity, this is a conductor composed of a group of wires or a combination of groups of wires twisted or braided together, but not insulated from one another. One wire or group of wires in a stranded conductor is a *strand.*

Stranded Conductor Sizes. According to the Standardization Rules of the American Institute of Electrical Engineers, the sizes of solid wires shall be stated by their diameter in mils, the American Wire Gage (Brown & Sharpe) sizes being taken as standard. The sizes of stranded conductors shall be stated by their cross-sectional area in circular mils. For brevity, in cases where the most careful specification is not required, the sizes of solid wires may be stated by the gage number in the American Wire Gage, and the sizes of stranded conductors smaller than 250,000 circular mils (i.e., No. 0000 A.W.G. or smaller) may likewise be stated by means of the gage number in the American Wire Gage of a solid wire having the same cross-sectional area. Furthermore, an exception is made in the case of "flexible stranded conductors." (Conductors of special flexibility should ordinarily be made with wires of regular A.W.G. sizes, the number of wires and size being given. The approximate gage number or approximate circular mils of such flexible stranded conductors may be stated.) In stating large cross-sections, it is sometimes convenient to use a circular inch (507 sq. mm.) instead of 1,000,000 circular mils.

According to the American Standard Specification for Bare Concentric Stranded Copper Cable for general use in the manufacture of covered or insulated conductors, there are five class designations:

AA for special cable, also commonly used for bare overhead conductors.

A for weather-resistant (weatherproof); slow burning; and slow burning, weather-resistant (weatherproof) cable.

B for cable insulated with various materials such as rubber, paper, varnished cloth, asbestos, asbestos-varnished cloth, and for cable indicated under Class A where greater flexibility is desired.

C & D for cable where more flexibility is desired than in previous classes.

The size and number of conductors for each size of cable is specified in this standard for each of these various classes of cable.

Stranded Wire. A group of small wires, used as a single wire is called a "stranded wire." There is no sharp dividing line of size between a stranded wire and a cable. If used as a wire, for example in winding inductance coils or magnets, it is called a "stranded wire" and not a cable. If it is substantially insulated, it is called a "cord."

Strap Cam. This is a cam often used for the operation of automatic screw machines, in which guide strips or straps are bolted to a cylindrical drum in order to provide the required cam surface. The object of the strap cam is to make it possible to easily change the action of the cam by moving the straps to different positions on the drum or by replacing them when a different shape is required.

Strenes Metal. A chromium-nickel-molybdenum alloy that can be cast to shape, eliminating a large amount of machine work and stock removal. Up to 500 hours of machining time has been saved by the use of this metal for a single large die. In the plant of a refrigerator manufacturer, dies from this metal are said to have produced more than 1,350,000 refrigerator top stampings from 0.050-inch material. Suitable for drawing and forming dies, punches, forming pads, and draw- or pressure-rings.

Strength. The strength of a metal is a measure of its ability to resist the application of load without rupture or appreciable permanent deformation.

Strength of Materials. See kind of material.

Stress Definitions. A *stress* is a force acting within a material or machine part resisting deformation. A load tends to produce deformation and is resisted by the stress which it creates within the body. A *working load* is the maximum load applied to a material under ordinary working conditions. A *working stress* is the stress produced in the material by the working load. A *safe working stress* is the maximum permissible working stress under given conditions, as for example, for a certain material. The *total stress* is the sum of all the stresses caused at one section of the body, irrespective of its area in square inches; whereas the terms *stress, working stress,* or *intensity of stress* generally mean the number of pounds stress per square inch of section.

Stresses, Compound. See Compound Stresses.

Stresses, Fatigue. See Fatigue Stresses.

Stress Relieving. Stress relieving or the reducing of residual stresses in a metal part is accomplished by heating the part to a suitable temperature, and holding it at this temperature for a time before permitting it to cool. See also Annealing.

Stress Theories. If a part must be designed to withstand compound stresses, it is essential to consider the combined effect of such stresses upon the safe-load capacity of whatever part is being designed. Opinions differ, however, as to the theory upon which formulas for combined stress calculations should be based. Three principal theories have been advanced. These are (1) the maximum strain theory; (2) the maximum stress theory; and (3) the maximum shear theory. Formulas based upon all of these theories are in use, and while the results obtained by these formulas may differ considerably, the factor of safety is ordinarily large enough to more than compensate for whatever differences or inaccuracies may be due to the particular formula employed. It does not follow, however, that these different formulas for compound stresses may be used interchangeably for all classes of work. For example, a formula based upon the maximum shear theory applies only to ductile material, such as steel, and would be unsuitable for cast iron. It is claimed, however, by some investigators that the maximum shear theory for its particular field of application is more accurate than the older theories.

Maximum Strain Theory: According to the maximum strain theory, failure occurs when the maximum unit deformation or strain in the piece reaches a certain critical value; hence, the stresses as measured by deformations or the "true stresses" should be considered. In other words, this theory supposes that the thing which causes failure and which must be used as a criterion for safety is the amount of deformation or strain. With a modulus of elasticity, E, of 30,000,000 there is a deformation or strain of 0.001 inch in every inch of length with a simple stress of 30,000 pounds. If now 30,000 pounds is the elastic limit, then when we have compound stresses, failure will begin to occur whenever the net strain due to the action of all the stresses together becomes 0.001 inch per inch. This theory is generally credited to Saint-Venant but he attributed it to Mariotte. It is used to a considerable extent in Europe.

Maximum Stress Theory: The maximum stress theory supposes that failure and elastic limit are purely matters of stress in a given direction regardless of the existence of stresses in other directions. That is to say, if a stress of 30,000 pounds is the elastic limit for a simple stress in a testing machine, it will also be the elastic limit in any case of compound stresses if the stress in one direction is 30,000 pounds and regardless of the existence of lesser stresses, whether tension or compression, in directions

at right angles. According to Rankine, the yielding of a material subjected to combined stresses depends entirely upon the maximum apparent normal stress, and is independent of the apparent shear or other stresses which may act at right angles to it. It has been established, however, that ductile materials such as shafting steels generally fail in shear and not in tension or compression, the latter being the fundamental assumption of the maximum-principal-stress theory; consequently this maximum stress theory cannot be applied to such cases. For brittle materials, on the other hand, failure may, or may not take place in tension and this theory or a modification thereof may apply.

Maximum Shear Theory: The third and more modern theory of elastic failure is based on the fundamental assumption that the maximum intensity of shear in a ductile material is the factor which determines elastic failure. This maximum-shear theory agrees very nearly with the results of tests for ductile materials and is coming more and more into favor. Any case of direct tension or compression produces a tendency to slide and the failure is due to this. A compression failure illustrates this directly. A tension failure if carefully examined will show the same point. It was also known for many years before Guest's publication of the maximum shear theory, that at about the time the elastic limit was reached in a tension specimen, lines at an angle of 45 degrees began to appear, indicating failure by shear. This indicates that failure by tension and failure by compression are really only different aspects of failure by shear. Failure means the beginning of sliding which is not recovered when the stress is removed and gives permanent set, thus indicating the "elastic limit." It follows, therefore, that the elastic limit will be the same for tension as for compression. This is true for steel and other ductile materials and is in itself a point of evidence in favor of the maximum shear theory.

Cast iron has no elastic limit and the actions referred to do not occur, so that elastic failure does not exist in cast iron as called for by the maximum shear theory. As is well known, the action of cast iron is quite different in tension and compression. Some experimental work on cast iron indicates that rupture with compound stresses occurs when the maximum stress reaches the value causing rupture with simple tension. This, of course, may not mean that a safe compound stress with cast iron occurs when the maximum stress reaches the safe value for tension.

Rules for Maximum Shear Theory: The following rules should be used in determining failure according to the maximum shear theory.

When there are stresses in two directions at right angles, with no stress in the third direction, and with both stresses of the same

kind, that is, both compression or both tension, the equivalent simple stress is equal to the greater of the two stresses. In this case the maximum stress theory gives exactly the same results.

When there are stresses in two directions at right angles, with no stress in the third direction, and with the stresses of opposite kinds, that is, one tension and one compression, the sum of the numbers giving the two stresses gives the equivalent simple stress. That is to say, if we have tension of 10,000 pounds in one direction and compression of 5000 pounds in another direction, the situation so far as failure is concerned is exactly the same as if we had a simple stress in a testing machine of 15,000 pounds per square inch.

When there are stresses in all three directions at the same time and all of the same kind, that is, all tension or all compression, we subtract the minimum from the maximum of the three stresses to obtain the equivalent simple stress.

When there are stresses in three directions at the same time, one or more tension and one or more compression, the sum of the numbers giving maximum compression and maximum tension stress gives the greatest equivalent simple stress.

In the case of a beam at the point of maximum stress there is usually stress in a single direction, so that this stress is a simple one and we need make no use of the maximum shear theory. In case of a rotating shaft subject to bending and twisting at the same time, that bending moment, which, if existing alone, would give the same conditions so far as failure is concerned, is the square root of the sum of the squares of the actual bending and twisting moments as shown by the Guest formula. This is also equal to that twisting moment which, if existing alone, would give the same conditions so far as failure is concerned. In the case of a rotating wheel, such as a turbine disk, there are radial and tangential stresses which are both tensile stresses; hence, the greater of the two gives the equivalent simple stress, the same as if the maximum stress theory were used.

Stretch-Forming Sheet-Metal Parts. The stretch-forming process, which is utilized extensively by aircraft manufacturers, consists, briefly, in gripping and restraining a sheet or strip along two of its sides or ends (depending upon the shape of the unformed blank and required contour) and then subjecting it to the pressure of a punch of the required contour. The forming is done merely by stretching the sheet around the punch and without the use of a die. The pressure of the punch must be sufficient to stretch the material within its plastic range so that, when it conforms to the shape of the punch, excessive spring-back or distortion upon release will not occur. Since the sheet is gripped along two sides only, the stretching naturally occurs in one direc-

tion, and this principle is applied even when a contour must be formed both crosswise and longitudinally. In cases where a part has a double contour consisting, for example, of a deep curvature in, say, a crosswise direction and a shallow curvature in the longitudinal direction, the general rule is to grip or restrain the edges which are parallel to the shallow contour. In other words, the sheet is restrained in the direction of the deeper curvature or contour. In all stretch-forming operations, the object is to stretch the material just enough to obtain a permanent set, thus avoiding excessive strain or rupture. The stretching action occurs throughout the thickness of the sheet; hence spring-back of the material is minimized.

Striking Points. Striking points are marks made on the guide of an engine to show where a special mark made on the cross-head would register with them if the connecting-rod was of such length that the piston would just strike the cylinder head at the corresponding end of the stroke.

String Forging. String forging is the process of forging a number of similar parts at once by means of dies having a number of depressions side by side.

String Milling Fixture. The term "string milling fixture" is often applied to that class of fixture in which the castings are placed in a row on the milling machine table, extending in a direction parallel to the line of travel of the table. With such an arrangement, provision is made for milling all of the castings with a single cutter, or gang of cutters, mounted on the arbor. In some cases, however, it may be found more desirable to set up the work in fixtures that provide for holding the castings or forgings side by side, instead of end to end.

Stripper Plates. When punches and dies are used to perforate sheet stock, the latter will be carried upward when the punch ascends, unless there is some device to prevent this. The simplest arrangement for stripping the stock from the punch and one that is applied to most blanking dies, consists of a plate which is attached to the die and has an opening for the punch to pass through. Beneath this stripper plate there is a passageway or opening through which the stock is fed. Obviously, the space between the die-face and stripper plate must be greater than the thickness of the stock in order to permit the latter to be fed along easily. As the result of this play between the stripper plate and the die, the stock is distorted to some extent by the action of the punch. This distortion, in many cases, does not cause trouble, especially when the die simply cuts out plain blanks, but when a follow die is used and flat accurate blanks

are required, or when the operation is that of piercing a number of holes in sheets or flat plates, it is often necessary to hold the stock firmly against the die while the punches pass through it, in order to prevent any wrinkling or buckling.

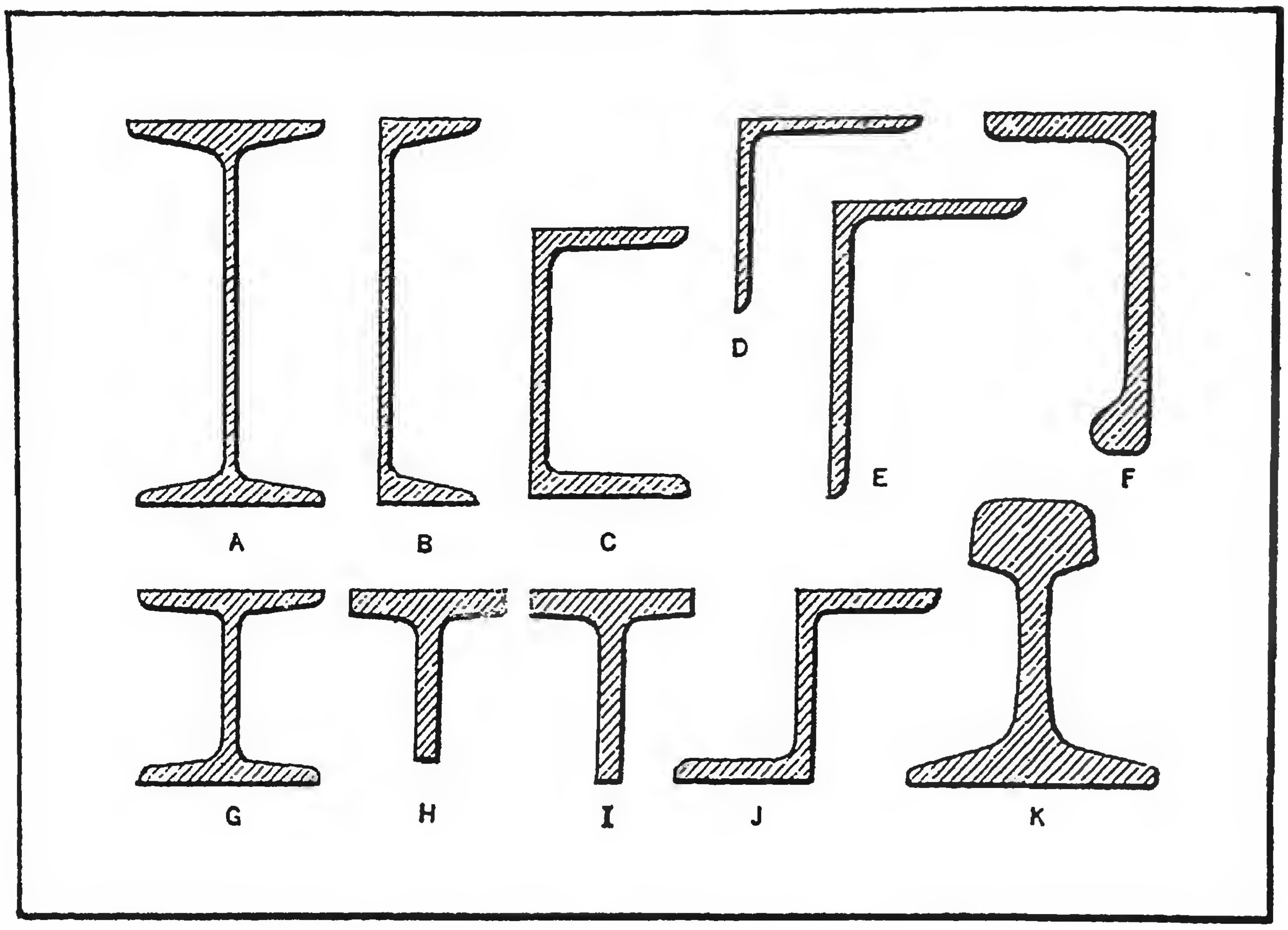
One method of preventing the stock from being wrinkled or distorted by the action of the punch consists in attaching the stripper plate to the punch-holder instead of to the die. Owing to the tendency that stationary stripper plates attached to dies have to distort pierced sheets, etc., some presses are equipped with cam-actuated stripper plates. The stripper plate moves up and down with the punches, so that the latter can be made shorter than would be possible with a stationary stripper, thus increasing their rigidity and durability. This method of stripping the stock is particularly adapted for gang punching and perforating operations, especially when the punches are small in proportion to the thickness of the stock and when it is essential to guide them close to the surface of the work.

Stroboscope. The stroboscope is an instrument, by the aid of which an observer may examine a point on a fast revolving mechanism, by a series of quick successive glimpses at that point, thus giving the mechanism the effect of being stationary. During the brief period of each glimpse, an impression is made on the retina of the eye, which remains until it is followed by the next glimpse, the whole succession of glimpses being woven into a continuous picture; the phenomenon is known as "persistence of vision."

The earliest form of stroboscope consists of a disk with a single hole in it, the disk being rotated in front of the mechanism to be examined, and at the same speed as the mechanism. Once every revolution the hole will come in the line between the observer's eye and the mechanism, giving the stationary effect.

Strontium. Strontium is one of the metallic chemical elements, the symbol of which is Sr, and the atomic weight, 87.63. The metal has a silver-white color. The specific gravity is 2.54. The melting point is at 830 degrees C. (1525 degrees F.). Strontium is found in small quantities in various rocks and soils, and in mineral waters. It is a ductile metal which oxidizes rapidly in the air and which burns when heated in the air or in oxygen.

Structural Shapes. Steel rolled to standard sections is widely used in building construction and in the manufacture of railway cars, agricultural implements, automobiles and numerous other products. By using a standard shape which is on the market and is adapted to a given structure or design, it is often possible to secure a stronger, lighter construction and a reduc-



Structural Steel Shapes Commonly Used

tion of manufacturing cost. Shapes which have been widely used are shown in the accompanying illustration. There are many other more or less special shapes for use in the agricultural, automotive, railway car, ship-building and other large industries.

Structural Beams: The structural or I-beam section is shown at *A*. The depths of these beams ordinarily range from 3 to 24 inches, although these figures and others to follow are intended to give a general idea of the minimum and maximum sizes ordinarily rolled, but they do not in all cases represent the absolute limits. The weights per foot vary from 5.7 pounds to 120 pounds for the small and large sizes mentioned. Each size, however, is made in different weights. There is also some variation in flange widths.

Channels: Structural channels (*B*), ordinarily range in depth from 3 to 18 inches, with weights per foot varying from about 4 to 58 pounds. Each channel size is made in three or four different weights. There is also some variation in flange widths. Ship-building channels have the same general shape as the structural channels but are somewhat lighter. Car-building channels (*C*) have wider flanges in proportion to the depth.

Angles: Equal angles (*D*) vary ordinarily in size from 1 by 1 inch up to 8 by 8 inches. The small size varies in weight from 0.8 to 1.49 pounds per foot, and the 8 by 8-inch size from 26.4 to 56.9 pounds per foot. Unequal angles (*E*) vary from 1¼ by

1½ inches up to 6 by 8 inches and each size is made in a wide range of weights. "Square root" angles are similar to equal angles except that each section of the former is rectangular, there being no fillet at the intersection or rounding of the outer corners.

Bulb Angles: Ship-building bulb angles (*F*) range from a 2½- by 1½-inch size up to the 10- by 3½-inch size. The minimum size mentioned weighs 2.66 pounds per foot and the large sizes either 33.2 or 35.2 pounds per foot. All except the very small sizes are made in two or three different weights.

H-beams: An H-beam section (*G*) is similar to the I-beam except that the flange width is equal to the beam depth. One large steel mill lists a minimum size of 4 by 4 inches and a maximum size of 8 by 8 inches.

Tees: Equal tees (*H*) range in size from 1 by 1 inch up to 6½ by 6½ inches, and with weights per foot of 0.89 pound and 19.8 pounds, respectively, for the two sizes mentioned. Unequal tees (*I*) may have a flange width which exceeds the stem (vertical section) depth, or this order may be reversed.

Zees: The flange widths and web heights of zees (*J*) range from 2 11/16 by 3 inches up to 3½ by 6 inches. The smallest zee mentioned weighs either 6.7 or 8.5 pounds per foot and the largest, from 29.4 to 34.6 pounds per foot. There are three different weights for each size excepting the very small sizes.

Railroad Rails: Railroad rails ordinarily vary in weight from 75 or 85 pounds per yard up to 140 or 150 pounds per yard. Weights from 90 to 110 pounds per yard have been used extensively; but on the main lines of the more important railroads where traffic is heavy, the weights may range from 120 to 150 pounds. The height of a 90-pound rail usually is about 5⅜ or 5⅝ inches, with flanged widths of 5⅛ and 5⅜ inches. The height of a 150-pound rail is 7¾ inches, with a flanged width of 6¾ inches. According to A.S.T.M. standard specifications, rails are made by the open-hearth process and of carbon steel. The carbon content increases as the weight of the rail increases. For weights from 70 to 84 pounds per yard, the carbon content is 0.53 to 0.70, whereas, for weights from 121 to 140 pounds per yard, the carbon content ranges from 0.69 to 0.82. The manganese content for the 70- to 84-pound rails is 0.60 to 0.90; and for the 121- to 140-pound rails, 0.70 to 1.00 per cent.

Structural Steel. Under the heading structural steel are included steels made either by the open-hearth or the Bessemer process, rolled to standard shapes suitable for structural purposes, and containing a smaller amount of carbon than that usually found in crucible or tool steel.

Structural Alloy Steels: When plain carbon steels are used for construction purposes, chemical analysis and tensile tests prove, in general, a fairly satisfactory indication of suitability, especially when the question of weight of construction is not of particular importance; however, the advent of high-powered machinery, and especially of automobiles and airplanes, has resulted in a demand for material that will withstand exceptionally high stresses, and the question of lightness is of prime importance. These demands have created a wide market for alloy steels which, incidentally, are used nearly always in the heat-treated condition. The study of alloy steels, and the specific influence of the metals entering into them involves, in addition to chemical and tensile tests, microscopic methods of examination, impact tests, vibratory tests, and various other tests, the object in each case being to reveal some new information that will assist the engineer in designing for maximum efficiency and light weight.

S.A.E. Standard Steels: The standard steel compositions of the Society of Automotive Engineers, Inc., include a large variety of both carbon and alloy steels. These steels are considered adequate for practically all parts made of ferrous materials that are necessary for the production of automotive apparatus, and include grades that have been found commercially available and technically adequate for the service required of such parts. Definite applications of S.A.E. steels are not specified as the selection of a proper steel for a given part must depend upon an intimate knowledge of a number of important factors, such as the availability and price of the material, the detailed design of the part and the severity of the service to be imposed, whether the part is to be forged or machined, machinability, and the method of manufacture.

Low-Alloy Structural Steel: The low-alloy structural steels now used in the construction of transportation equipment to reduce weight and increase the pay load differ from the more familiar types of alloy steels, such as the S A E series, in that they can be employed to advantage in the "as-rolled" condition. These low-alloy structural steels, of which Mayari R, produced by the Bethlehem Steel Co., is an example, are used without heat-treatment, except for the customary annealing of sheets. Their composition is selected to produce a material that will not harden appreciably in rapid cooling, so as to insure that thin sections and welds, or the steel adjacent to welds, will not harden and require heat-treatment, with its resulting increase in cost. Although the strength of these steels is appreciably higher than that of ordinary structural steel, it must not be excessively high, because of the fabricating difficulties that would be encountered.

The composition of Mayari R steel was selected to give the following properties: (1) A strength appreciably in excess of ordinary structural steel; (2) good hot- and cold-working properties; (3) good welding characteristics; (4) little tendency to harden on rapid cooling; and (5) high resistance to atmospheric corrosion.

To attain such a combination of properties, it is necessary that the carbon content be held low and that the increased strength be obtained by the use of elements other than carbon. The carbon content of Mayari R was, therefore, fixed at approximately 0.10 per cent, and the required strength and corrosion resistance are obtained by the addition of nickel, chromium, manganese, silicon, copper, and phosphorus.

Extensive research has indicated that Mayari R steels within the following ranges of composition have a minimum yield point of 50,000 pounds per square inch, a minimum tensile strength of 65,000 pounds per square inch, and meet the other requirements outlined: Carbon, 0.08 to 0.20 per cent; manganese, 0.50 to 1.00 per cent; phosphorus, 0.04 to 0.12 per cent; sulphur, 0.05 maximum; silicon, 0.05 to 0.50 per cent; chromium, 0.20 to 1.00 per cent; nickel, 0.25 to 0.75 per cent; and copper, 0.50 to 0.70 per cent. Tests of several years duration have shown that the corrosion resistance is about six times that of plain steel.

Structures, Vibration. See Vibration of Structures.

Strut. In engineering, a strut is a structural member the length of which is considerable in proportion to its width, depth, or diameter. See Column.

Stub's Iron Wire Gage. Same as Birmingham Wire Gage.

Stub's Steel. Stub's steel is used for small pins, studs, shafts, screws, etc., requiring strength and toughness. It can be easily machined and hardened, and has a bright finish. As a general rule, Stub's steel may economically be used where the largest diameter does not require further machining. Weight, 0.283 pound per cubic inch; 489 pounds per cubic foot. Specific gravity, 7.85. Strength: tension, 70,000 pounds per square inch. Melting point, 2600 degrees F.

Stub's Steel Wire Gage. This gage is used for drawn steel wire or drill rods of Stub's make, and also by a number of American drill rod manufacturers. It differs from Stub's iron wire gage which is the same as the Birmingham Wire Gage. The gage sizes may be found in MACHINERY'S Handbook.

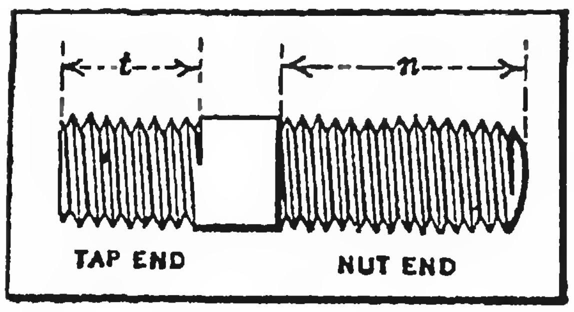
Stub-Tooth Gears. Most gears used in general machine construction have a total depth equal to 2.157 divided by diametral pitch. The stub-tooth form has less depth. There are different

standards for stub teeth. The American Standard has a total depth equal to 1.8 divided by the diametral pitch (see Gear Tooth Standards, American—20-Degree Stub-tooth).

Fellows System: The stub gear teeth introduced by the Fellows Gear Shaper Co. are based on the use of two diametral pitches. One diametral pitch, say, 8, is used as the basis for obtaining the dimensions for the addendum and dedendum, while another diametral pitch, say, 6, is used for obtaining the dimensions of the thickness of the tooth, the number of teeth, and the pitch diameter. Teeth made according to this system are designated as 6/8 pitch, 12/14 pitch, etc., the numerator in this fraction indicating the pitch determining the thickness of the tooth and the number of teeth, and the denominator, the pitch determining the depth of the tooth. The clearance is made greater than in the ordinary gear-tooth system and equals 0.25 ÷ diametral pitch. The pressure angle is 20 degrees.

Nuttall System: In a system of stub gear teeth originated by C. H. Logue of the R. D. Nuttall Co., the tooth dimensions are based directly upon the circular pitch. The addendum is made equal to 0.250 × the circular pitch, and the dedendum equal to 0.300 × the circular pitch. The pressure angle is 20 degrees.

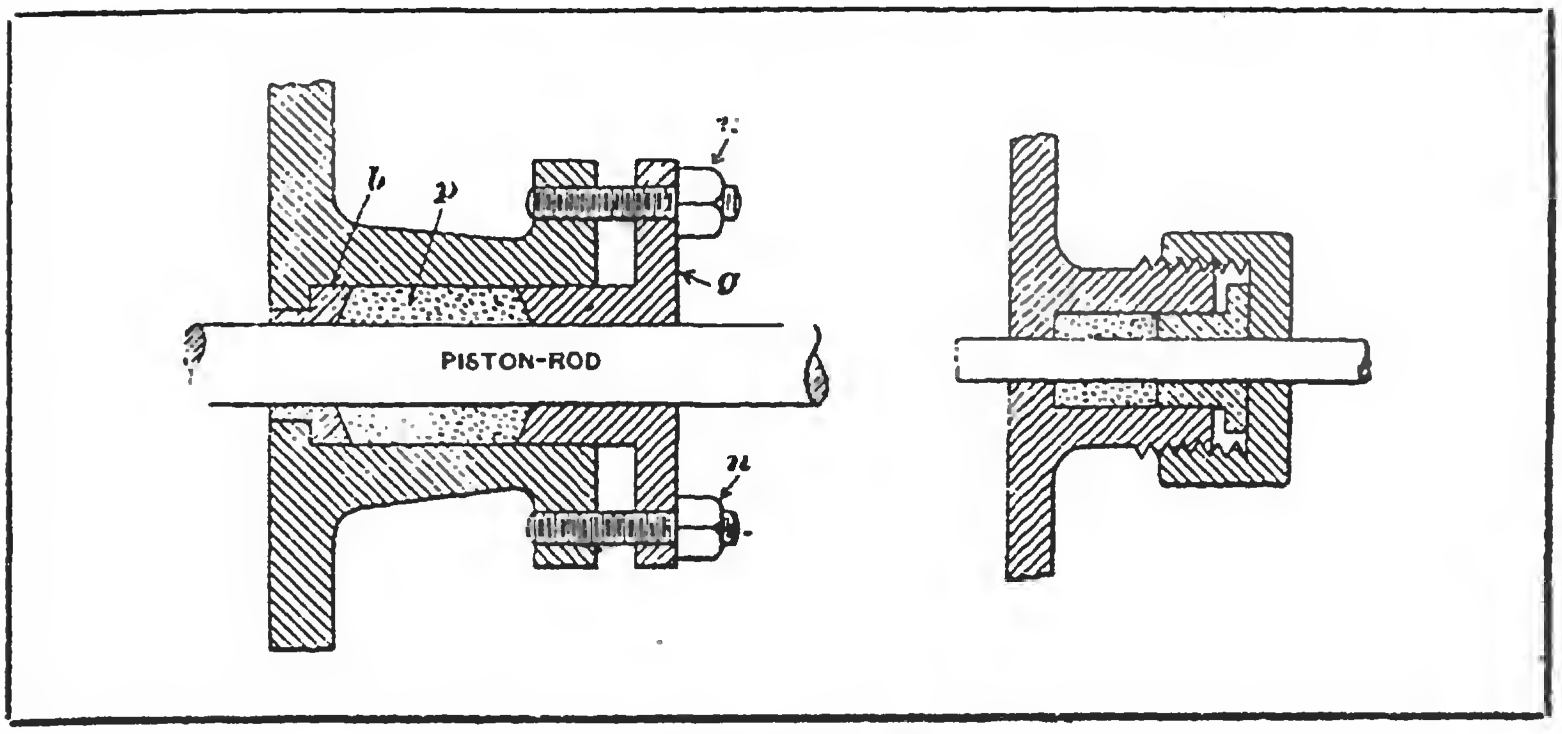
Studs. Studs or stud-bolts are cylindrical pieces having a thread on each end. A stud differs from a cap-screw in that a nut is substituted for a solid head. One end of a stud, as shown at *t* (see illustration), is for insertion in a tapped hole and the longer threaded end *n* is for receiving one or two nuts, a second lock-nut sometimes being used to hold the other in place. The thread on the short end is usually a little oversize to make it fit tightly into the tapped hole. The nominal length of a stud is the same as the total length. Studs are extensively used for holding cylinder heads, steam-chest covers, and similar parts in position, the nuts on the outer ends clamping the head or cover against the part into which the studs are screwed.



Stud of Common Form

Studs and Cap-screws: Studs are preferable to cap-screws for holding cylinder heads, covers, etc., for the following reasons: (1) A stud and nut can generally be screwed tighter than a cap-screw because of better alignment, smoother threads, and reduced effect of torsional elasticity. (2) A stud and nut are less likely to break than a cap-screw, when making repairs. In case a nut is rusted fast on a stud, it can be split with a cold chisel, but a cap-screw "seized" in the casting may be twisted off. This means that the broken part must be drilled out and a new cap-

screw provided to take its place. The loss of time and extra labor incident to breakages of cap-screws are important disadvantages when making repairs. (3) Covers secured with nuts and studs can be loosened and tightened without serious deterioration of the fastening means. The nuts on studs can be loosened many times without appreciable wear of the threads, but not so with cap-screws. They soon wear the cast-iron threads and become loose and are likely to strip after being used a few times. (4) Studs have the advantage of holding gaskets in place while a cover is being applied. This is an important advantage in erecting, when the parts are heavy and applied with difficulty. (5) A stud made from a round bar is stronger than a cap-screw turned down from a hexagon bar.



Stuffing-boxes

Stud Setting. The screwing of studs into the tapped holes of some part such as a steam cylinder, pump cylinder, etc., is known as *stud setting.* Studs may be screwed into place either by hand or power. Special stud-setting chucks are often employed. One type is so arranged that it can be used for either studs or nuts, and the jaws open automatically and release either the stud or nut, as the case may be, just like a die of the self-opening type, and without stopping or reversing the spindle of the machine. There is also an adjustable friction type of chuck which must be reversed and screwed off of a stud. When setting nuts with this type, the machine must be stopped each time to disengage the holder from the nut.

Stuffing-Box. This term is applied to a cylindrical chamber which surrounds a rod and is used in conjunction with a gland and holding device, for retaining packing in such a way as to prevent leakage. The left-hand diagram shows a common form of stuffing-box for a piston-rod. The packing *p* is placed in a

chamber surrounding the rod and is held in place by the gland *g* which may be adjusted by means of the nuts *n*. The bushing *b* is usually made of bronze, which, being softer than the rod prevents it from wear, and is easily replaced when the hole through it becomes enlarged or oval in form. The bottoms of the stuffing-box and gland are usually turned to a bevel, as shown, which has the effect of forcing the packing against the rod when soft or fibrous kinds are used. A typical stuffing-box for valve rods of small size is illustrated at the right. This is similar in construction to the one just described, except that the gland is held in place by a screw-cap instead of by bolts. The bottoms of the stuffing-box and gland are square in this case, which is better for some of the special forms of packing now used.

Sub-Bituminous Coal. This is also known as lignite, black lignite, brown coal, and lignitic coal. It is a kind of coal containing less than 50 per cent of carbon, resembling bituminous coal, it being black and shiny, but disintegrating more rapidly than bituminous coal when exposed to the air. It has a heating value per pound of combustible of from 11,000 to 13,500 B.T.U.

Submerged Body Weight. See Buoyancy.

Sub-Press. A sub-press cannot be defined as a special class of die, but merely as a principle which may be applied in constructing different kinds of dies. The sub-press principle is simply that the upper and lower portions of the die are combined into one self-contained unit so arranged as to always hold the upper and lower members in exact alignment with each other. A common form of sub-press construction consists of a base which is clamped to the press, a frame or "barrel" fitted to the base, and a plunger which slides vertically in an adjustable babbitt bearing. The plunger head is connected to the press slide. The compound type of die is commonly used in a sub-press. The upper die is located in the plunger and the lower die in the base. This sub-press construction permits of a high degree of accuracy as it insures an accurate alignment of the various members of the die.

The sub-press die was originated in watch and clock factories for performing blanking operations requiring great accuracy, and, at the present time, dies built on the sub-press principle are employed for a great variety of work in connection with many different lines of manufacturing. Sub-presses are largely used for producing such parts as small wheels and gears and other delicate parts for clocks, watches, meters, time recorders, and other similar pieces which must be made with great accuracy and uniformity. Although, in some cases, one sub-press can be made to take several sets of punches and dies, it is customary,

and generally advisable, to have a separate sub-press for each set, as one of the advantages gained in using the sub-press is in being able to quickly change from one die to another; when separate sub-presses are used this can be done by simply loosening the clamps, changing the presses and reclamping. In addition to this advantage, there is no time wasted in aligning the punches and dies; moreover, the danger of shearing the punch or die, as a result of careless alignment, is entirely eliminated. Another advantage of the sub-press, dependent in part upon the accuracy of alignment provided, and the corresponding accuracy in fitting which can be given to the cutting edges, is that the work is remarkably free from fins and burs.

Substations. The term "substation" is applied to a building, room, or outdoor area equipped for the conversion of electricity by means of converters, rectifiers, or motor-generator sets; for the raising or lowering of voltage by means of transformers; for changing the frequency; or for interconnection, distribution, and switching. Sometimes a single station will serve all of these purposes. A substation may be manually operated, automatically controlled, or remote controlled.

Sub-Surface Milling. The term "sub-surface milling" has sometimes been applied when a tilted type of rotary milling machine is used in conjunction with an auxiliary reservoir in which cutters and work can be submerged in a bath of cooling compound while the milling operation is being performed.

Sub-Zero Treatment of Steel. The sub-zero treatment of steel consists in subjecting the steel, after hardening and either before or after tempering, to a sub-zero temperature (which usually ranges from −100 degrees F. to −120 degrees F.) and for a period of time varying with the size of volume of the tool, gage or other part. Commercial equipment is available for obtaining these low temperatures.

The sub-zero treatment is employed by most gage manufacturers in order to stabilize precision gages and prevent subsequent changes in size or form. Sub-zero treatment is also applied to some high-speed steel cutting tools. The object in this case is to increase the durability or life of the tools; however, up to the present time the results of tests by metallurgists and tool engineers often differ considerably and in some instances are contradictory. Methods of procedure also vary, especially in regard to the order and number of operations in the complete heat-treating and cooling cycle.

Suction. Pumps for liquids, if located at some point above the source of supply, perform two separate operations when in use; first the water or other liquid is made to flow into the pump

cylinder through a "suction pipe," and then it is forced out of the cylinder through a discharge or delivery pipe leading to any desired point. The flow of the water up to the cylinder is caused by a partial vacuum within the cylinder produced by the action either of a reciprocating piston or a rotating wheel or rotor, depending upon the type of pump. This vertical movement of the water in the pipe, or lift, is due to the fact that the atmospheric pressure on the surface of the water at the source of supply is no longer counteracted by an equal pressure inside the pipe; consequently, the water is forced upward and this is commonly referred to as "suction." The suction pipe should be free from air leaks, because a very small leak will affect the operation of the pump, especially if the lift is quite high. It is advisable to test the suction line with a pressure of at least 25 pounds per square inch. See Pump Suction; also Lift of Water Pumps.

Suction and Discharge Pipes. The area of the suction and discharge or delivery pipes of pumps is based upon the velocity of flow through them. For pipes approximately 25 feet in length, the velocity of flow should not exceed 200 feet per minute; for lengths of about 50 feet, the velocity should not exceed 180 feet per minute; for lengths of 100 feet, the maximum velocity should be reduced to about 150 feet per minute; and for lengths of 125 feet, the maximum velocity should be about 125 feet per minute. The area of pipe for a given velocity of flow may be determined by the following formula in which S_a = area of suction pipe in square inches; P_a = area of piston or plunger in square inches; S = piston speed in feet per minute; V = velocity of flow of water through the suction pipe in feet per minute.

$$S_a = \frac{P_a \times S}{V}$$

The velocities previously given will allow for two or three elbows, a stop valve, and a foot-valve. The area of the discharge pipe may be found by using the same formula and substituting 300 for the value of V in all cases.

Sulphate of Lime. Same as Calcium Sulphate.

Sulphate of Magnesia. Same as Magnesium Sulphate.

Sulphur. Sulphur is widely distributed in nature, both in the free state and in combination. The most important deposits are in Sicily. It is found in many of the important iron ores and is, therefore, generally present in iron and steel. The sulphur contents in steel must be reduced as much as possible, because sulphur, if present in too great a percentage, injures the steel. Sulphur is one of the non-metallic chemical elements, the symbol of which is S, and the atomic weight, 32.07. Commercial sulphur

forms yellow crystals, melting at 113 degrees C. (235 degrees F.), and boiling at 445 degrees C. (833 degrees F.). The specific gravity of sulphur is 2.06, and the specific heat, 0.171. Sulphur ignites in air at a temperature of 363 degrees C. (685 degrees F.). It is a poor conductor of electricity.

Sulphuric Acid. Sulphuric acid (chemical formula, H_2SO_4), frequently also called "oil of vitriol," is a colorless liquid, when in its pure state. The commercial acid has a slightly dark tint. Concentrated acid is heavier than other acids, its specific gravity, when 98.5 per cent pure, being 1.84. The commercial acid has a specific gravity of about 1.72. When this acid is mixed with water, heat is evolved, and the mixing must be done slowly. *The acid must be added to the water and not the water to the acid,* as, in the latter case, a violent explosion is likely to occur. When pure, sulphuric acid is a dense, oily, colorless, odorless liquid with a specific gravity of 1.838 at 15 degrees C. (59 degrees F.). The specific heat is 0.330. It boils at 338 degrees C. (640 degrees F.), and, at 400 degrees C. (752 degrees F.), the vapor dissociates into sulphur trioxide and water; at 10.5 degrees C. (51 degrees F.), the acid freezes to a colorless crystalline mass. When mixed in the proportion of 4 parts of acid to 1 part of water, the temperature is raised 100 degrees C. (180 degrees F.). Sulphuric acid is exceedingly corrosive and decomposes animal and vegetable substances by the aid of heat. It has a great affinity for water and unites with it in all proportions; it unites with moisture from the atmosphere and becomes weaker when exposed. Sulphuric acid of commerce is never pure; it may contain lead sulphate absorbed from the lead chambers during the process of manufacture, arsenic, and other substances.

Sunk Key. A sunk key, as its name implies, is sunk into a shaft. With this type of key, which is the one most commonly used, care should be taken to secure a good bearing on the sides. Ordinarily, the bearing at the top and bottom of a sunk key should be comparatively light, although, in some cases, when it is used to resist endwise movement, as well as a rotary movement, it is given a heavy bearing on all sides. The principal bearing, however, should not be, in any case, at the top and bottom, as it is then more likely to work loose than when fitted tightly at the sides.

Superficial Hardening. When low-carbon steel is subjected to the cyanide hardening process, a very thin but extremely hard surface is obtained, and this is known as superficial hardening. This hard outer skin may be only a few thousandths of an inch thick, and this is the important difference between superficial hardening and ordinary casehardening. See Cyanide Hardening.

"Superfinishing" Process. The term "superfinish" has been applied to a finish of fine quality obtained by a process developed in the mechanical laboratories of the Chrysler Corporation for application to certain automotive parts. This process may be used in finishing flat, round, concave, convex, and other surfaces. The finish is obtained mechanically and the machines used vary in design to suit the shape and size of the work. The finish is produced by stones, which are comparatively hard and of medium grit and operate with a "scrubbing action." The object in superfinishing, as in honing, is to eliminate minute scratches and surface defects created by previous mechanical operations and produce a bearing surface in which any remaining scratches will be below the mechanically made bearing surface. This process may be applied to such parts as cylinder bores, pistons, crankshaft bearings, cams, etc.

In the process, ordinary abrasive stones of proper grain and hardness, acting in a suitable lubricant and under sufficient pressures progressively applied, are brought into contact with the metal surface to be superfinished. At least three motions are required to produce superfinish and five or more are desirable. Equipment is in use that has as many as ten motions operating simultaneously. As the result of this multi-motion scrubbing with abrasives, the superfinished surface need have no indentation deeper than a few millionths of an inch.

Superfinished surfaces, in a bearing, can move on each other with a very thin lubricating film and a minimum of clearance. Two metal surfaces are said to be lubricated when there is a sufficient number of oil molecules between them to maintain fluid friction and completely separate the bearing surfaces under a normal bearing load. Projections above the bearing surface of the metal will rupture the oil film, with a resulting bearing failure. Superfinished surfaces have no metal projections above the bearing surface to break the oil film so that complete lubrication can be assured. Superfinish is also applied to advantage on many non-lubricated surfaces. See also Finish or Surface Quality.

Superfinishing Machines: Machines for superfinishing may be designed for a given class of work or for general application. The Foster general-purpose superfinisher may be applied to cylindrical parts in a range of diameters and lengths. This machine is being used for a wide variety of processes. It is adapted for superfinishing leader pins and die sets, cylindrical gages, draw-mandrels, pump pistons and shafts that pass through packing, motor armature shaft bearings, bearings on small crankshafts, etc. Superfinishing machines for general application to flat surfaces have also been developed.

Superfinishing Heads for Lathes: These superfinishing heads are mounted on the compound rest of an engine lathe cross-slide. With this arrangement, practically any cylindrical work within the capacity of the lathe can be superfinished. Special heads can also be made for boring mills, grinders, and other machinery. The superfinishing heads have a wide range of uses.

Superheated Steam. Superheated steam is produced by adding heat to saturated steam after it has been removed from contact with the water from which it was formed. This is accomplished by passing the steam through superheater coils after it leaves the boiler drums. The superheater coils usually are located in the path of the hot gases from the boiler furnace from which the coils absorb a portion of the waste heat as it passes off to the stack. The earliest recorded attempt to use superheated steam in a steam engine is that of Richard Trevethick, an Englishman, who, in 1832, used superheated steam in a condensing pumping engine making eight revolutions per minute and having a boiler pressure of 45 pounds per square inch.

Why Superheated Steam is Used: The greatest thermodynamic loss in the steam engine—with the exception of the heat lost in the exhaust, which may be partially recovered, because exhaust steam can be used for such purposes as heating buildings and feed water—is the loss of heat due to initial condensation and re-evaporation in the cylinder. In the ordinary steam engine, this loss will amount to as much as 20 per cent of the entire steam fed to the cylinder. The explanation of this great loss is as follows: The steam which enters the cylinder of an engine comes in contact with cylinder walls which are at a temperature lower than that of the entering steam, owing to the fact that steam at the lower temperature of the exhaust has just left the cylinder. Instantly, therefore, a thin film of steam is condensed upon the cylinder walls, thus decreasing the volume of the steam admitted, so that the total weight fed to the cylinder per stroke is in excess of that which would have been fed had there been no condensation. Later, during expansion, when the energy of the steam is being converted into useful work, and its temperature has fallen, part of the steam which originally condensed on the cylinder walls is re-evaporated because the temperature of the steam has fallen below that of the cylinder walls, causing a natural flow of heat from the cylinder walls to the body of the steam. The heat necessary to accomplish this re-evaporation is wasted, because it does no useful work. The varying difference in temperature between the steam and the cylinder walls, therefore, causes a double loss in initial condensation and in the subsequent re-evaporation. The amount of initial condensation can be figured by noting the

difference between the actual amount of steam used per stroke, as shown by the amount of boiler feed water, or the condensate from the cylinder, and the amount per stroke accounted for by the indicator card at cut-off. By comparing the amount of steam in the cylinder, at the point of cut-off, as accounted for by the indicator card, with the amount in the cylinder at the point of release, as accounted for by the indicator card, it is possible to form an idea of the amount of steam which has been re-evaporated during the stroke.

Now, if superheated steam be used in the cylinder instead of wet or saturated steam, loss of heat will lower the temperature of the steam without condensing it, if the degree of superheat be high enough, as no condensation of steam can occur until all of the superheat is removed. Subsequently, then, there will be no re-evaporation of moist steam, as no moisture has been formed. Moreover, the change in the original volume of the steam due to decreasing the degree of superheat is negligible compared with that caused by condensation, so that the weight of steam is not appreciably affected thereby; also, the difference in temperature of the cylinder walls has less effect, as superheated steam is a very poor conductor of heat compared with saturated or wet steam.

Supplement of Angle. The supplement of a given angle (a) equals $180° - a$; hence, if angle a exceeds 180 degrees, the supplement is negative. The supplement angle of a 120-degree angle equals $180 - 120 = 60$ degrees.

Surface Combustion. If a mixture of gas and air, which is being emitted at a high velocity from a Bunsen burner, is permitted to strike against a piece of red-hot firebrick held a short distance away from the front of the burner, the mixture will burn at the surface of the firebrick. This constitutes the principle from which the method of what is called *surface combustion* have been developed. In the practical application of surface combustion, an explosive mixture of gas and air in the proper proportions for complete combustion, or with air in slight excess, is caused to burn without flame in contact with a granular incandescent solid, whereby a large proportion of the potential energy of the gas is immediately converted into radiant form. The principle is the same as having a multitude of small burners instead of one or a few large burners. The advantages claimed for the system are that the combustion is greatly accelerated by the incandescent surface, and can be concentrated just where the heat is required; the combustion is perfect with a minimum excess of air; the attainment of very high temperatures is possible; and owing to the large amount of radiant energy developed, the trans-

mission of heat to the object to be heated is very rapid. Boilers arranged for surface combustion have a mixing chamber in front of the tubes and connecting with them. The tubes contain the granular refractory material. The gas mixture is forced through the tubes at a high velocity, and complete combustion is insured after the gas has traversed a very short distance. The remainder of the granular material in the tubes acts as a baffle for hot gases, forcing them toward the walls of the tubes in order that a large proportion of the heat may be given over to the water. Surface combustion fires can be run efficiently at temperatures in excess of 3000 degrees F. It is possible to consume efficiently a volume of gas equivalent in heating power to 150 pounds of coal per hour per square foot of fuel bed while not more than from 60 to 70 pounds per square foot of grate area can be burned on locomotive boiler grates. This intensity of fuel consumption coupled with almost perfect combustion produces an intensely hot radiant fire. There being no excess of air, a minimum of heat is carried off in the waste gases.

Surface Condenser. In this type of condenser for condensing exhaust steam from engines or turbines, the condensing water and the steam are kept separate, the condensation being effected by the contact of the steam with metallic surfaces cooled by the continuous circulation of the water. A surface condenser consists mainly of a condensing chamber containing horizontal tubes connecting with small chambers at each end, separated from the main chamber by heads or tube sheets. The exhaust steam from the engine or turbine enters the condensing chamber, while the cooling water, forced by a circulating pump, passes through the tubes.

Surface Finish. Some terms relating to surface finish are contained in the American Standard B46.1, *Surface Roughness, Waviness and Lay,* and are given as follows:

*Roughness: R*elatively finely spaced surface irregularities, the height, width, and direction of which establish the predominant surface pattern. Irregularities produced by cutting edges and machine tool feed may be considered roughness. *Roughness Height* is rated in microinches as an arithmetical average deviation from the mean surface. The arithmetical average (AA) deviation from the mean surface is obtained by an instrument which, in effect, takes a great many measurements of the heights of the peaks and valleys of the surface (measured from the mean surface) and averages them. This gives a roughness height rating value that is somewhat less than the root-mean-square (rms or RMS) average deviation formerly in wide use. (The root-mean-square average is obtained by squaring the height measurements of the

peaks and valleys, taking the average of the squared values, and then extracting the square root of this average square). *Roughness Width* is rated in inches as the maximum permissible spacing between repetitive units of the surface pattern.

Waviness: Irregularities of the nominal surface which are of greater spacing than roughness. These irregularities may result from such factors as machine or work deflections, vibration, heat treatment, or warping strains. *Waviness Height* is rated in inches as the peak-to-valley distance. *Waviness Width* is rated in inches as the spacing of adjacent waves.

Roughness-Width Cutoff. The maximum width in inches of surface irregularities to be included in the measurement of roughness height. The roughness width is used to establish the roughness-width cutoff value which, unless otherwise specified, is always greater than the roughness width. Standard Roughness-Width Cutoff values are: 0.003, 0.010, 0.030, 0.100, 0.300, and 1.000 inches.

Lay: The direction of the predominant surface pattern, produced by tool marks or grains of the surface ordinarily determined by the production method used.

Flaws: Irregularities which occur at one place, or at relatively infrequent intervals in the surface, such as a scratch, ridge, hole, peak, crack or check.

Microinch: The microinch (abbreviation, mu. in.) equals one millionth (0.000001) inch. This is a common unit of measurement employed in surface measurement research and in establishing standard roughness unit values.

Various methods have been developed for checking or measuring surface irregularities. Some of these are intended primarily for use in the research laboratory or inspection department, whereas others are particularly suitable for use in the shop.

Comparison with Standard Specimens: In plants where surface roughness values are specified, it is essential to provide some method of checking which may readily be applied in the shop wherever finishing operations require roughness checks.

Comparison of a machined surface with a standard finished sample or specimen may be made by the sense of touch. A simple method is by dragging the finger-nail first over the standard block and then the "lay" or ridges of the machined surface.

Commercial Sets of Standard Finish Specimens: A number of sets of standard surface specimens of finish samples have been placed on the market. These sets consist of blocks which have surfaces varying from the smoothest to the roughest likely to be required. Some of these specimen blocks are made of stainless steel. An aluminum alloy has been employed in at least one case, and in another a hard black plastic material is used so that mere brilliance, which often is very deceptive, is elimi-

nated in comparing the finish on the work with that of the sample. Specifications for physical specimens of surface roughness and lay for various types of machined surfaces are given in American Standard ASA B46.2-1952.

Comparing Finishes by Projection Method: This method of inspecting and comparing surface finishes with approved standards is suitable for either shop or laboratory. A small piece of clear plastic film ("Faxfilm") is softened by the use of a solvent and then is pressed into the surface, thus transferring the unevenness to the film. This film is next mounted in a 2-inch square frame which may be labeled for identification and future use. The surface pattern on the film is enlarged to 100 diameters or more if required, by means of a projector, thus permitting comparison with another film. Comparator apparatus is available for projecting simultaneously both the test specimen and a standard finish specimen.

Tracer Method of Determining Surface Quality: This method consists in tracing across the surface with a diamond or sapphire contact point which is displaced as it passes over the minute hills and valleys of the surface. These movements of the finely pointed tracer are magnified and either indicated by a meter or, with another type of instrument, are recorded graphically on a chart. The tracer point method provides a practical indication of surface roughness values. Two commercial tracer-type instruments are the Profilometer and the Brush Surface Analyzer.

Profilometer: In measuring surface roughness with this instrument, the surface irregularities are measured and averaged as a diamond tracer point moves slowly across the surface, and a meter shows by direct reading the average deviation in micro-inches. The profilometer may be applied to flat, cylindrical or curved surfaces. Different types of tracers are obtainable to permit checking various kinds of surfaces, such as small holes, narrow slots, etc.

Brush Surface Analyzer: This instrument produces on a graduated chart a graphic ink-line record of surface irregularities showing not only the amplitude, but the form of these irregularities showing not only the amplitude, but the form of these irregularities greatly magnified. The surface is traced or explored by a stylus having a point radius of 0.0005 inch. The displacements of this stylus by the surface irregularities are finally recorded in ink on a moving paper chart.

Surface Gage. The surface gage is used extensively for scribing lines that represent finished surfaces, and also for testing the parallelism between a surface and the table of a machine, such as the planer or shaper. A common form of surface gage has rather a heavy base on which is mounted a rod carrying a

pointer or scriber. The latter can be adjusted in or out, and it can also be moved to any position along the rod.

Surface Grinding Machines. The grinding of plane or flat surfaces is known as surface grinding, and there are several different types of machines used for this work. The surface grinder is indispensable in the tool-room for truing parts that have been distorted by hardening and for producing fine accurate surfaces. Many of the surface grinding machines built at the present time are also efficient for producing flat surfaces in connection with manufacturing operations. Ordinarily, the surface grinder is used for finishing parts which have been milled or planed approximately to size, although many pieces are ground from the rough on the large machines used for manufacturing purposes. Surface grinders vary both in regard to the form of the grinding wheels used and the movement imparted to the work-table when grinding. For instance, the work-tables on some machines operate with a reciprocating motion, whereas others rotate; the grinding is done on some machines with a disk-shaped wheel, whereas other machines have a cup- or ring-wheel. Some of these grinders are comparatively small in size and light in construction and are designed more particularly for tool-room use, whereas others are large and powerful, and are employed for grinding duplicate parts in connection with manufacturing operations.

Horizontal Face Grinding Machines: Surface grinding machines of the horizontal face-grinding type have a grinding wheel of the ring or cylinder form, the face or edge of which is used for grinding; hence, the name "edge grinder" is applied to machines of this class by some manufacturers. The face grinder is preferable for certain classes of work to the type of machine using a wheel that grinds on the periphery. The horizontal face grinder, which has a horizontal wheel spindle, and work-table, is especially adapted to that class of work which can be held to better advantage when the surface to be finished is in a vertical plane as the edge of the ring wheel is vertical. For example, the ends of rather long castings, such as machine legs, etc., can easily be ground on this style of grinder, because the work can readily be clamped to the table of the machine in a horizontal position. The horizontal face grinder is used in locomotive shops for truing or finishing the bearing surfaces of guide-bars and can be employed to advantage for many other grinding operations.

Vertical-spindle Surface Grinders: Many vertical-spindle surface grinding machines are in use which have a cup- or ring-wheel and a rectangular work-table that has a reciprocating motion when the machine is in operation and grinding rectangular surfaces or parts that should move in a straight line beneath

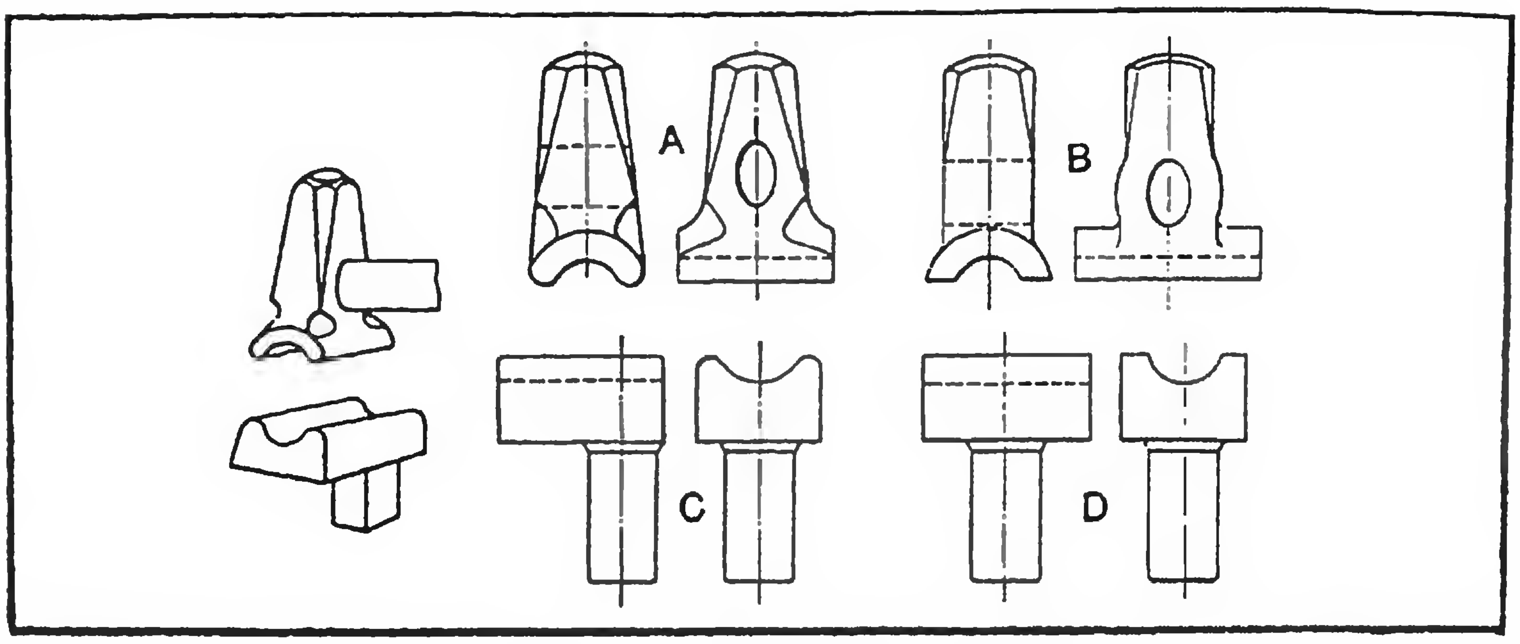
the wheel. The length of the table stroke is controlled by dogs in the usual manner. Rotary attachments or circular work-tables are often supplied with such machines so that the sides of saws, rings, or flat disk-shaped parts may be rotated while being ground by placing them on the rotary table or chuck which is mounted on the grinder table, the table remaining stationary. This type of grinder can be used advantageously for grinding long rectangular surfaces or disk-shaped parts (by using the circular attachment), and it is very efficient for grinding a number of small castings simultaneously.

Some vertical-spindle surface grinders have a rotary work-table. One of these larger designs, which is intended for grinding duplicate parts in connection with manufacturing operations, has a rotary work-table which is mounted on a slide that enables the table to be withdrawn from under the wheel, and in a position convenient for loading with new parts to be ground.

Surface Plate. Surface plates have plane or flat surfaces and are used in machine construction for testing flat surfaces and other parts and also as a base-plate from which to measure in laying out work. Usually they are made of hard close-grained cast iron, either square or rectangular in shape, and vary in size from a few inches to several feet in length and width. The method of originating straightedges by fitting three together until any two are a perfect fit (as near as can be determined by a practical test) can also be applied to the making of surface plates. Obviously, if only two plates are put together, they may not have true plane surfaces, even though they show a good bearing when tested. This is because the inaccuracy in one plate will often be concealed by corresponding inaccuracies in the other. Therefore, to secure accurate results, three plates should be scraped in together, these being numbered 1, 2, and 3. First, fit Nos. 3 and 2 to No. 1. When this has been done, Nos. 2 and 3 are, practically speaking, duplicates. The second step is to fit Nos. 2 and 3 together by scraping about as much from one plate as from the other in order to reduce any error which may have been copied from No. 1; third, fit No. 1 to No. 2; fourth, fit No. 3 to No. 1; fifth, fit No. 2 to No. 3 by scraping as much from one plate as the other. Continue this series of operations carefully until plate No. 1 will fit Nos. 2 and 3, and No. 2 will fit Nos. 1 and 3. Having originated three plates in this way, one can be laid aside to be used as a master plate for testing the others which are employed in active service.

Surface Roughness. See Surface Finish.

Surfaseal. A rubber paint that offers an affectual protective coating on metal and withstands an unusual amount of abrasion.



Swages used in Hand Forging

Can be applied to any metal surfaces. For best results, the surface is sand-blasted and a Surfaseal primer is applied. When the primer has dried, Surfaseal No. 2 is brushed on. To withstand severe abrasion, several coats may be applied twenty-four hours apart.

Surveyor's Measure. 1 mile = 8 furlongs = 80 chains; 1 furlong = 10 chains = 220 yards; 1 chain = 4 rods = 22 yards = 66 feet = 100 links; 1 link = 7.92 inches.

Swage. The term *swage* applies to a number of different kinds of tools with hollow impressions in their faces, but the most common kind is for finishing plain round work. Swages are made in pairs, top and bottom to match. The depth of the impression ought to be about one-third the diameter of the piece the swages are intended to finish. In the accompanying illustration *A* represents the correct style of top swage, and *B* an objectionable style; *C* shows the correct style of bottom swage, and *D* the incorrect style.

Swaging. Cold swaging is a method of reducing or forming steel or other material, while cold, by means of a machine that caused the work to be struck a large number of successive blows by a pair of dies or hammers. This process is applied principally to the reduction of wires, rods, and tubes, either for tapering or pointing the ends or reducing the diameter in one or more places, and it is the only method by which rolled or plated stock can be reduced without destroying the plating or coating. For this reason, swaging is largely employed in connection with the manufacture of jewelry, spectacle parts, fancy pins, etc. The method is also extensively used for pointing rods or tubes which are to be drawn. The millions of needles, bicycle spokes, button-hooks, crochet needles, and similar articles which are produced annually indicate some of the possibilities of the swaging process. The rotary swaging machine having dies mounted in the revolving

head is the type commonly used, although the horizontal design having dies which operate in a horizontal direction is used for some purposes.

Swaging by Hot Process. The hot-swaging of metal has been found especially economical in the making of carbon steel drills and end-mills and for the manufacture of motorcycle pedal pins, spinning spindles used in the cotton industry and similar parts. The rolls that impart a radial movement to the dies of a cold-swaging machine are carried by a cage having a floating or slow rotary movement. This construction causes a sliding blow to be delivered to the work, which is suitable for the cold-swaging process, but not for hot-swaging. One design of hot-swaging machine head is so arranged that the rolls rotate on their axes while held in a fixed position; as a result the blows are delivered directly and quickly to the work without producing any torsional effect. The severe service imposed upon a machine by the swaging of hot metal demands a heavily constructed machine and means for keeping the dies cool. In one type of machine this is accomplished by placing a water jacket around the head roll bearing.

Swaging Dies. Swaging dies for use in power presses are a type in which parts are formed to the required shape by compressing the metal so that the impressions in the punch and die-faces are reproduced upon the work; in other words, instead of shaping the metal by cutting, bending, or drawing, it is formed by compression. The pressure required for swaging is relatively high because it must be sufficient to cause the metal to flow into the punch and die-cavities or depressions.

Sweating. When parts are soldered together by heating them sufficiently to melt the solder, instead of using a soldering iron, the operation is often known as *sweating*. Brass boxes for engine connecting-rods are sometimes sweated together prior to machining, in order to hold the two halves in alignment while finishing the sides and boring. The finished surfaces forming the joint between the brasses are first tinned or covered with solder. This is done by heating the brasses enough to melt the solder, then applying a flux (such as sal-ammoniac), and finally the solder. After tinning, the brasses are again heated if the solder has hardened; they are then put together and allowed to cool. The halves are separated after machining by heating them until the solder melts, after which the sweated surfaces are cleaned off.

Swing. As applied to a lathe, the swing is the maximum diameter that may be turned without interference from the machine's ways or other parts.

Swing Crane. The name swing crane is applied to pillar cranes that have a rotary motion only, but which are not provided with a trolley on a horizontal arm. The name is also applied to jib cranes if they are not provided with a trolley.

Swing-Frame Grinding Machines. The swing-frame grinding machine was designed for the purpose of removing the fins, gates, and wires left by and in molding, from castings too heavy to be conveniently lifted by hand. One wheel only is mounted on a machine, and the arm on which the wheel is mounted has a large radius of swing and is designed, in some cases, to travel laterally on a track. Swing-frame machines are the heavy-duty machines in the foundry and are rigidly constructed. Great pressure of the wheel on the work is possible, because at times the operator bears his whole weight on the handles of the machine.

Swiss Pattern Files. These are used by tool and die makers, model makers and delicate instrument part finishers. They are made to closer tolerances than the conventional American pattern files although with similar cross-sections. The points of the Swiss pattern files are smaller, the tapers are longer and they are available in much finer cuts. They are primarily finishing tools for removing burrs left from previous finishing operations, truing up narrow grooves, notches and keyways, cleaning out corners and smoothing small parts.

Swiss Screw Thread. This is a thread system originated in Switzerland as a standard for screws used in watch and clock making. The angle between the two sides of the thread is 47 degrees 30 minutes, and the top and bottom of the thread are rounded. This system has been adopted by the British Association as a standard for small screws, and is known as the British Association thread.

Switches. See Control Switches; Disconnecting Switches; Motors, Control Equipment.

Switches, Air-Break Type. An air-break switch has contacts which make and break contact in the air as contrasted with an oil switch in which the contacts make and break under oil. The air-break switch may be enclosed by some form of cover for the purpose of protecting the operator or to prevent unauthorized operations. Air-break switches can be used up to any voltage or current commercially feasible. The construction varies according to requirements. There are several kinds, such as lever, brush, rotary, plug, and push-and-pull switches.

Switches, Oil Type. An oil switch is a device for closing and opening an electrical circuit by the movement of contact parts

which make and break contact while submerged in oil. Some manufacturers apply the term "oil switch" when the device is used only to open an unloaded circuit or a loaded circuit, at the will of the operator; and the term "oil circuit-breaker" is used when the switch is utilized to break the circuit automatically under abnormal conditions. This distinction, although considered correct by the American Institute of Electrical Engineers, is not universally accepted. Oil switches are used almost invariably on alternating-current systems. They are used on low-voltage circuits when air-break switches are objectionable, either because of head-room, limited space for connections, or where the open arc is a source of danger; and on high-voltage circuits, where air-break devices are not practicable, owing to the space required for breaking a high-voltage arc in air. The fact that the oil switch breaks the arc under oil makes it especially valuable for service in plants where inflammable or explosive dust or gases are prevalent; in cotton mills, where lint or oil would make an air-break switch objectionable; in powder mills, chemical factories, or gaseous mines; or under any conditions in which an air arc might cause a short-circuit or a ground of some adjacent circuit. Oil switches are particularly effective on alternating-current circuits, because, as the switch contacts separate, the oil surrounding the contacts immediately rushes to fill the space in the break between the contacts, and introduces a high resistance which is in proportion to the speed at which the contacts part. Also, the pressure of the oil confines the arc to a limited area and tends to quench it. When the voltage passes through zero, the resistance of the oil tends to prevent the arc from re-establishing. The oil switch is not nearly so effective on direct current. As there is no zero potential point in this case, the breaking of a direct-current circuit under oil results in severe burning of the metal and oil, and the generation of much gas; consequently, there is considerable tendency of the arc to hold between the opening contacts. However, oil switches are sometimes used on direct-current circuits where conditions are such that to break an arc in the open air is prohibitive. There are several factors to be considered in selecting oil for use in an oil switch; namely, flash point, burning point, viscosity, and cold test. The flash and burning points must be high. The oil used should be obtained from the oil switch manufacturer or ordered from specifications furnished by him.

Swivel Base. The lower part of a chuck, vise, slide, or other machine part is called a swivel base when it is so arranged that it can be turned or rotated about a center, so that the chuck, vise, etc., attached to it may be turned to any angle. The swivel base is generally graduated to show the angle.

Symbols, Mathematical. See Mathematical Symbols.

Synchronism. Synchronism expresses the phase relationship between two or more periodic quantities of the same period when the phase difference between them is zero.

Synchronism Indicators. The synchronism indicator or synchroscope, as it is called, affords a quick and safe means for paralleling alternating-current machines, as it shows when the machines are in phase and in step, indicating by the position of a pointer the difference in phase relations between the machines, and showing whether the incoming machine is running too fast or too slow. It is superior to synchronizing with lamps, because the latter give no indication of the relative speed of machines; the lamps will indicate when the machines are of the same frequency, but the phase relations can be judged only by the brilliancy of the lights.

Synchronous Condenser. When a synchronous motor is operated idly, that is, without carrying any mechanical load, and simply supplies a wattless current for correcting the power factor of an installation, it is termed a *synchronous condenser.* It is used for power-factor correction and for maintaining constant voltage by power-factor control.

Synchronous Converters. The synchronous converter is a rotating machine for converting alternating current into direct current or vice versa. In the former case, it is called a *synchronous converter;* in the latter, an *inverted synchronous converter.* The term *rotary converter* is also frequently used. While a motor-generator set requires two machines, as the name implies, the synchronous converter consists of only one machine.

In general, the construction of a synchronous converter is similar to that of a direct-current generator with the addition of collector rings connected to the armature winding at equal distances around the armature. It differs, however, in several important details, notably in the shape of the pole tips and the addition of heavy copper dampers in the pole faces to prevent unstable operation and to assist in starting from the alternating-current side. No transfer of mechanical energy takes place in synchronous converters, because the torque consumed by the generation of the direct current and the torque produced by the alternating current are applied at the same conductors. As a result, the mechanical parts of a synchronous converter can be made much smaller than the corresponding parts of a direct-current generator.

Synchronous converters are built in single-, two-, three-, and six-phase, but, owing to the very general use of three-phase trans-

mission, only the last two types are, as a rule, standardized. More than 90 per cent of the alternating-current systems in the United States are of either 25- or 60-cycle frequency; these frequencies, therefore, have been adopted as standard for synchronous converters. The 25-cycle is mainly used for power and railway work, and the 60-cycle, for lighting service.

Synchronous Generator. See Generators, Alternating-current.

Synchronous Motors. The synchronous motor is essentially a synchronous generator with reversed rotation, and, in general, any alternator will operate as a synchronous motor or vice versa. There are, however, certain features wherein the motor differs from an alternator, as in the addition of a starting winding. The stator of a synchronous motor is constructed in exactly the same way as that of a synchronous generator. It is commonly called the *armature.* The rotor of the synchronous motor is called its *field;* it consists of a *field spider* which is mounted on the shaft the same as the rotor spider of an induction motor, but which carries *field poles* instead of laminations with slots and windings. The poles are usually of laminated sheet steel, the individual sheets usually being several times thicker than those of the armature punchings. Usually the starting winding consists of a number of copper bars which extend across the pole faces and are connected at each end by a short circuiting ring. In starting, then, the motor acts like a squirrel cage motor until it reaches a velocity of about 95 per cent of synchronous speed when the motor "pulls-in" to step with the rotating magnetic field. Synchronous motors run at constant speed and in the smallest sizes are used for timing applications such as electric clocks. The large sizes are used to operate pumps, compressors, rolling mills and in motor generator sets.

Synchroscope. A synchroscope, or synchronism indicator, is a device which, besides showing when two alternating-current systems are in synchronism, also indicates which system has the higher frequency, the difference in frequencies, and the phase relation when the frequencies are equal. They are commonly of the dynamometer or the moving-iron types, being similar in their operation to power-factor meters in that their indications are dependent upon the phase difference between two currents.

Synthetic Chemistry. Synthetic chemistry is that part of chemistry which deals with the building-up of more complicated from less complicated substances. The term "synthetic" is also used for substances made by artificial means in the laboratory to distinguish them from like substances obtained direct from plants and animals.

T

Tachagraph. The tachagraph is a tachometer of a very sensitive type. It is used to measure minute changes of speed within a single revolution and produce an autographic diagram of the angular velocity.

Tachometer. Tachometers are made in different types for indicating the speed in revolutions per minute of rotating shafts, the peripheral speeds of flywheels or pulleys, the lineal speed of belts or hoisting ropes, and various other speed measurements. Tachometers may have a dial graduated to represent revolutions per minute and an indicating hand which gives the direct reading, or the instrument may make a permanent record of the speed by drawing a line upon a graduated chart. Some of these recording tachometers or tachographs have a dial in addition to the recording chart. Precision instruments are also made for testing the angular variations of flywheels, variations in the speed of machines due to slipping of belts, or any irregularity in running. An *electric tachometer* of the type generally used may have the indicating or recording instrument located at any distant point from the shaft, the speed of which is to be recorded.

Tailstock. A tailstock is that part of a machine tool, such as an engine lathe or cylindrical grinding machine, which is used to support upon a conical center the outer end of a rod, shaft, or other piece which is being turned or ground. The body forming the tailstock may be clamped in different positions along the machine bed for accommodating work of different lengths, and the tailstock spindle containing the supporting center is adjustable to allow for small variations in length. The upper part of a lathe tailstock body is adjustable in a lateral direction so that the axis of the work may be inclined relative to the movement of the tool carriage, in order to turn tapering parts when the lathe is without a taper attachment.

In bench lathe practice, the tailstock is frequently used as a means of holding and feeding various classes of tools. Tailstocks for bench lathes are made in several different forms. The type intended primarily for supporting one end of centered work is designed along the general lines of the engine lathe tailstock. Then there is a lever-operated tailstock for drilling, reaming, counterboring, and similar operations. Another form is operated through a rack and pinion in conjunction with a hand-lever. The cross-slide adjustment provided in this case is useful for recessing, facing, and counterboring. The "half-open" tailstock is

employed for light operations such as drilling, reaming, lapping, and the cutting of very small threads with taps or dies, while the revolving-spindle tailstock is applied to certain drilling operations. The "sliding" or "open" tailstock is similar to the half-open design, except that it has full or complete bearings. The spindle has a knob at one end and is moved by hand the same as the spindle of a traverse grinder.

Talc. Talc is a mineral known as steatite or soapstone. Chemically, it consists of magnesium silicate ($H_2Mg_3Si_4O_{12}$). Steatite or soapstone is usually a white or gray substance. The specific gravity varies from 2.6 to 2.8. Its extreme softness and the fact that the surface feels greasy make it easily recognized. Talc has been experimented with as a lubricant similar to graphite. It is, however, not acted upon by tannin solutions, like graphite, but it may be brought into a fine molecular state by heating with ammonium carbonate or by exposing it for several hours to a current of dry ammonia. The talc is afterward dried in a vacuum. The treated material can be suspended in water, so that it is very difficult to filter it, and subsides exceedingly slow in lubricating oils of medium density. When once suspended in a neutral oil, the talc does not subside on heating. The change in the character of the talc is attributed to the absorption of a minute quantity of ammonia. From 40 to 60 per cent of ordinary talc may be introduced into heavy mineral oil, provided the oil be added to the talc and the operation not carried on in the reverse manner.

Tandem Dies. See Follow Dies.

Tangent, Arc. See Arc Sine and Tangent.

Tangential Load. A load applied to a circular body, such as a gear or pulley, in the direction of a tangent to its circumference, is known as a tangential load. To find the tangential load at the pitch-line of spur gearing, multiply 33,000 by the number of horsepower being transmitted, and divide the product by the pitch-line velocity in feet per minute.

Tangent of Angle. See Functions of Angles.

Tang of Drill Shank. The "tang" is the flat end on the tapering shank of a drill. The drill is caused to rotate with the spindle or socket, principally by the friction between the shank and the socket, and any slipping is prevented by the flat end or tang on the shank which engages a cross-slot at the end of the taper hole. The drills used in chucks ordinarily have straight shanks instead of the taper form and the end does not have a tang.

Tantalum. Tantalum is a metal of silver-white color, highly ductile, and remarkably hard, if hammered. Tantalum has a specific gravity of 16.64. It melts at a temperature of 2850 degrees C. (about 5160 degrees F.). Its specific heat is 0.0365, and its coefficient of linear expansion per unit length, per degree F., 0.0000045. Tantalum belongs to the same group of metals as vanadium and columbium.

Tap Bolt. A tap bolt is used without a nut, the threaded end being screwed into a tapped hole in one of the parts to be held by the bolt; hence, the name, tap bolt. Tap bolts and cap-screws are used in the same way.

Tap Drill Diameters. Tapping troubles are often caused by using tap drills that are too small in diameter. For ordinary manufacturing, not more than 75 or 80 per cent of the standard thread depth is necessary, and for some classes of work not more than 50 per cent is required. Tap drill sizes, especially for machine screws, should be varied according to the material to be tapped and the depth of the tapped hole. The diameters of tap drills can be found by the formula $D = T - 0.75 \times 2\,d$, in which D = drill diameter; T = diameter of tap or thread; d = depth of thread.

The diameters obtained by this formula allow for a thread having 75 per cent of the standard depth which is sufficient for general work. The full depth of an American Standard thread equals 0.6495 times the pitch of the thread, and the full depth of a British Standard Whitworth thread equals 0.6403 times the pitch.

Tape-Controlled Machines. The basic principle of controlling machine tools by means of a punched tape is not new. The punched tape has long been used to operate piano keys—in the case of the old player-piano—or to control the movement of the warp threads in the Jacquard loom, but it was not until about 1950 that it was introduced as a means of controlling the movements of a machine tool.

The tape may be paper or plastic, with punched holes, or it may be magnetic and quite similar to those used in sound recorders. It may also take the form of punched cards. Other types of tape control make use of finely ruled lines on a glass plate, called diffraction gratings, and musical notes recorded on magnetic tape.

The first step in applying tape control is to prepare the tape. This may be done in several ways. With one system, the machine operator machines the first workpiece, using regular manual controls and working slowly to be sure that every operation is exactly correct. As he does this, the tape is being

fed through the machine controller and each tool movement recorded by a small punch which punches holes in the tape. After the operation is complete, a fresh workpiece is loaded into the machine and the tape played back at full speed to machine it automatically.

With another system, the engineering department prepares the tape. First of all, the dimensions on the drawing are reduced to units corresponding to the increments of movement of the tool slides. These are written on a chart which is then translated into punched holes on a machine similar to a typewriter. The machine operator then receives a tape rather than a drawing of the new part he is to produce. If the parts are to be produced in quantity, the tape may be in the form of a loop which will continue to feed through the controller and produce parts, twenty-four hours a day if necessary, until the order is completed.

If the volume of production requires a second or third machine to be employed, exact copies of the tape are quickly made on a duplicator and, provided the machines are all in top condition, parts produced by one machine will be identical (within allowable tolerances) with those from another machine. The tremendous advantages of this system are obvious. A plant a thousand miles from the home plant can produce identical parts without the errors that always occur when an attempt is made to copy cams and other mechanical control equipment. All that is necessary is to ship a strip of tape and feed it into a similar machine. If design changes must be made, a piece can be cut out of the tape and a new section prepared and spliced in. This can also be done at the remote plant by telegraphing the change on a machine similar to a teletypewriter. Indeed, an entire tape can be prepared at the remote plant by feeding the master into the teletypewriter and reproducing a copy at the other plant.

When a job is completed, the tape is removed and stored in a tape library, filed by work part number. When a new order is received, the operator merely draws the tape from storage, makes the necessary machine set-up, and starts producing parts with the complete assurance that they will be exactly the same as the previous order.

To facilitate tape preparation, some plants keep a stock of ready-made tapes for standard operations, such as opening and closing chucks, feeding stock, centering and cutting off. These are easily spliced to the sections which must be prepared specially for a new job, thus reducing the total preparation time.

Taper. See Brown & Sharpe Taper; Jarno Taper; Morse Taper.

Taper Attachment, Engine Lathe. Turning tapers by setting over the tailstock center has some objectionable features. When the lathe centers are not in alignment, as when set for taper turning, they bear unevenly in the work centers, because the axis of the work is at an angle with them; this causes the work centers to wear unevenly and results in inaccuracy. Furthermore, the adjustment of the tailstock center must be changed for turning duplicate tapers, unless the length of each piece and the depth of the center holes are the same. If the tailstock center is offset for taper threading, a "drunken thread" or one which does not follow a true helix will result, owing to an irregular turning movement. To overcome these objections, many modern lathes are equipped with a special device for turning tapers, known as a *taper attachment,* which permits the lathe centers to be kept in alignment for taper work the same as for cylindrical turning, and enables more accurate work to be done.

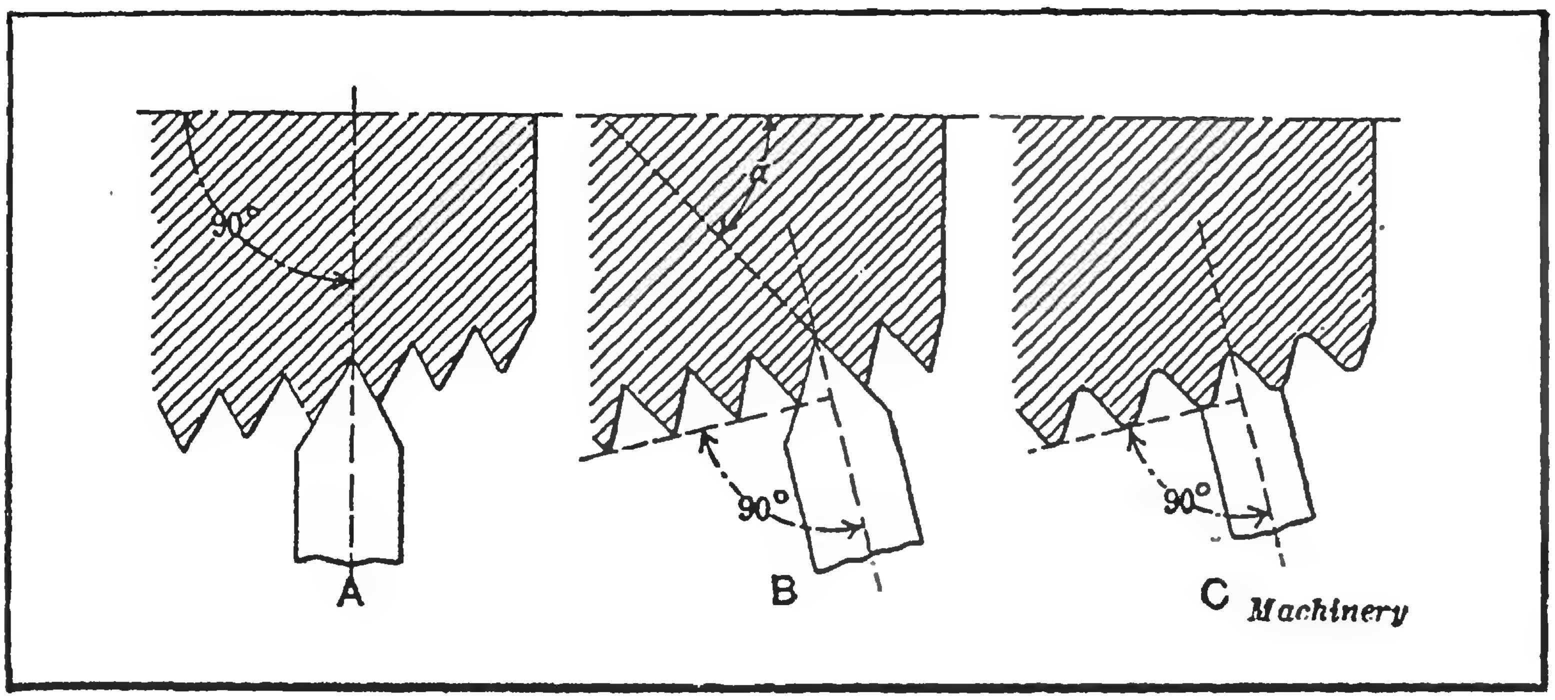
Taper Pins. Taper pins are used as a means for securing two parts of a machine or device to each other; the most common application is for securing collars or hubs to shafts. The standard taper is ¼ inch per foot. The pins of different sizes are known by numbers. The diameters at the large ends of pins of the American Standard vary from 0.078 inch for pin No. 6/0 to 0.706 inch for pin No. 10.

According to the British Standard, the taper is ¼ inch per foot and the large end diameters vary from 1/16 to ½ inch.

Tapers for Machine Tool Spindles. Various standard tapers have been used for the taper holes in the spindles of machine tools, such as drilling machines, lathes, milling machines, or other types requiring a taper hole for receiving either the shank of a cutter, an arbor, a center, or any tool or accessory requiring a tapering seat. The Morse taper represents a generally accepted standard for drilling machines. The headstock and tailstock spindles of lathes also have the Morse taper in most cases; but the Jarno, the Reed (which is the short Jarno), and the Brown & Sharpe have been used to a limited extent. Milling machine spindles formerly had Brown & Sharpe tapers in most cases; but in 1927, the milling machine manufacturers of the National Machine Tool Builders' Association adopted a standard taper of 3½ inches per foot. This comparatively steep taper has the advantage of insuring instant release of arbors or adapters. The No. 30 taper has a large end diameter of 1¼ inches; No. 40, 1¾ inches; No. 50, 2¾ inches; and No. 60, 4¼ inches. The British Standard for milling machine spindles is also 3½ inches taper per foot. This standard includes the following large end diameters: 1⅜ inches, 1¾ inches, 2¾ inches, and 3¾ inches.

Taper Thread Cutting. A tool for cutting tapered screw threads should be set as shown at *A*, or so that the sides of the thread incline equally with reference to a line perpendicular to the axis of the screw. The principal reason why taper threads should be cut with the tool in this position is that taper taps are made in this way or with the threads normal to the axis. If the tool were set in the position shown at *B* or *C* or so that the sides of the thread incline equally with reference to the tapering surface, obviously such a thread would be a poor fit in a hole tapped with an ordinary taper tap having threads normal to the axis as at *A*. If the hole and the tapering part which screws into it were both threaded normal to the surface as at *B*, the thread would be satisfactory unless there were an unusual amount of taper. In extreme cases, angle a (see diagram *B*) of one side of the thread might be so small that the radial or bursting pressure on the nut would be excessive owing to the wedging action.

Tap Extractor. The best and quickest method of removing a broken tap is by using a tap extractor. A design which has proved successful is equipped with projecting fingers which enter



Correct and Incorrect Positions of Tool for Taper Thread Cutting

the flutes of the tap which is backed out of the hole by turning the extractor with a wrench. This extractor is adjustable so as to support the fingers close to the tap, even when the broken end is below the surface of the work. Another method of removing broken taps, which has proved effective in some cases, is to inject into the hole a little nitric acid, diluted in the proportion of about one part acid to five parts water. The action of the acid upon the steel loosens the tap so that it usually can be removed either with an extractor or an ordinary pair of pliers. The re-

maining acid should afterwards be washed out of the hole so that it will not continue to eat the threads. A third method consists in adding, by electric arc welding, metal onto the shank of the broken tap, up to or above the level of the work. Care must be exercised to prevent depositing metal onto the threads in the tapped hole. After the shank has been built up, the head of a bolt or a nut is tacked to it and then the tap may be backed out.

Tap-Holder, Friction. Many tapped holes do not extend clear through the work, but are "blind"; hence, when the tap is driven by power, provision should be made for allowing the tap to stop in case it should strike the bottom of the hole, as otherwise it might be broken. Taps are also broken frequently, because the drilled holes are not large enough, the result being that the strain

Mark	Meaning of Mark
NC	American National Coarse Thread Series
UNC	Unified and American Coarse Thread Series
NF	American National Fine Thread Series
UNF	Unified and American Fine Thread Series
NEF	American National Extra Fine Thread Series
UNEF	Unified and American Extra Fine Thread Series
N	American National 8, 12 and 16 Thread Series (8N, 12N, 16N)
UN	Unified and American 12 and 16 Thread Series (12UN, 16UN)
NH	American (National) Hose Coupling and Fire Hose Coupling Threads
NM	National Miniature Screw Thread
NGO	American (National) Gas Outlet Thread
NS	American Special Thread (60° thread form)
NPT	American (National) Taper Pipe Thread
NPTF	Dryseal American (National) Taper Pipe Thread
PTF	Dryseal SAE Short Internal Taper Pipe Thread
ANPT	Military Aeronautical Pipe Thread Specification MIL-P-7105
NPS	American (National) Straight Pipe Thread
NPSC	American (National) Straight Pipe Thread in Pipe Couplings
NPSF	Dryseal American (National) Fuel Internal Straight Pipe Thread
NPSH	American (Standard) Straight Pipe Thread for Hose Couplings and Nipples
NPSI	Dryseal American (National) Intermediate Internal Straight Pipe Thread
NPSL	American (National) Internal Straight Pipe Thread for Locknut Connections (loose fitting mechanical joints)
NPSM	American (National) Internal Straight Pipe Thread for Mechanical Joints (free fitting)
NPTR	American (National) Internal Taper Pipe Thread for Railing Joints (mechanical joints)
AMO	American Standard Microscope Objective Thread
ACME C	Acme Screw Thread — Centralizing Type
ACME G	Acme Screw Thread — General Purpose Type
STUB ACME	Stub Acme Threads
N. BUTT	National Buttress Screw Thread

Significance of Markings on Taps

on the tap becomes excessive, and breakage occurs unless provision is made for limiting the amount of driving power. One method of safeguarding the tap is to hold it in a friction chuck or holder, which will slip in case the tap strikes the bottom of the hole or meets with excessive resistance to rotation. There are a number of different forms of friction tap- and drill-holders on the market. These differ as to the method of obtaining and varying the frictional resistance. On some drilling machines, an adjustable friction is introduced in the spindle-driving mechanism to prevent the breaking of taps.

Tap Marking. All taps are marked with the nominal size, number of threads per inch and the proper symbol to identify the thread form. Taps having multiple threads are marked with diameter, number of threads per inch, form of thread and lead designated in fractions, also double, triple, etc. For example: A 1"-8 double thread special tap with National form of thread will be marked as follows:

1"-8NS Double
¼" Lead

Left-hand taps are marked "Left Hand" or "LH" as follows:

1"-8NS Double LH
¼" Lead

Tapped Hole Accuracy. Cut thread taps made to American Standard specifications, when used under normal conditions, should, in the majority of cases, produce holes within Class 2 tolerances of the American Standard for Screw Threads. Ground thread taps made to these specifications, when used under normal conditions, should, in the majority of cases, produce holes within Class 3 tolerances of the American Standard for Screw Threads.

Tapper Taps. Tapper taps are used extensively by nut manufacturers. They differ from so-called "nut taps" in that the thread is not tapered at the point, but simply chamfered. Tapper taps with nut tap thread occasionally are required.

Tapping Attachments. Some drilling machines are equipped with special gearing which can be utilized for reversing the rotation of the spindle when tapping, so that a special reversing tap chuck is not necessary. This mechanism for reversing the spindle when the tap has reached the required depth is often known as a tapping attachment.

Tapping Chuck of Reversing Type. In tapping by power, the tap ordinarily is fed down into the hole to the required depth and its rotation is then reversed for screwing it out of the hole. There are different methods of obtaining this reverse motion.

When the tapping is done in an ordinary drilling machine, special tap chucks are frequently used which are designed to reverse the rotation of the tap when the latter has reached the required depth. One form of tap-holding chuck is so arranged that the tap automatically stops when it strikes the bottom of the hole or when an adjustable depth gage comes against the top of the work. The raising of the spindle then reverses the tap which backs out at an increased speed.

Tapping Lubricants. Experiments have proved that the power required in tapping—that is, the resistance to the action of the tap when threading a nut—varies considerably with different lubricants. The following lubricants reduce the resistance to the cut when threading forged nuts, as well as those made from hexagon drawn material; the threads in the nut have a good finish and appearance: Stearine oil, lard oil, sperm oil, rape oil, and a mixture of 10 per cent graphite with 90 per cent tallow. A mixture of cutting emulsion with water also reduces the resistance to the threading action fairly well. In tests with emulsion, it was noted that it made very little difference how much water was mixed with the emulsion. A mixture of one part emulsion to 160 parts of water proved practically as good as a mixture of one part emulsion to ten parts of water.

Compound oils, that is, mineral oils mixed with animal or vegetable oils of the type usually employed for cooling lubricants for turning and milling, produce a considerably higher resistance than the animal or vegetable oils and cannot, therefore, be recommended for tapping. Mineral oils not mixed, and ordinary lubricating and machine oils, are wholly unsuitable. The resistance to cutting is very great, the taps break, and the threads in the nuts are badly torn; ordinary water reduces the cutting resistance better than some of the compound oils. Animal and vegetable oils, therefore, ought to be used exclusively for tapping.

Experiments on Lubricants for Tapping: Experiments conducted at Gothenburg, Sweden, on a large scale, indicate that the generalizations made from the earlier experiments, as recorded in the foregoing, are correct. Animal and vegetable oils are the best for tapping mild steel, and of these stearine oil and "Winter-strained" lard oil are preferable. Mineral oils—machine oil—were found to be wholly unsuitable. Compound oils containing less than 50 per cent of animal or vegetable oil acted much the same as the mineral oils and cannot be recommended for threading. When the compound oils contained over 50 per cent animal or vegetable oil, they could be used and were then found to be almost as good as the pure animal and vegetable oils.

A few emulsions have given almost as good results as animal and vegetable oils, but the kind of emulsion used plays an im-

portant part, and the majority of emulsions do not give good results. In almost all the tests made, a large volume of lubricant gave somewhat better results than a small quantity. This was particularly evident in the case of the thinner oils. Kerosene, turpentine, and graphite proved unsuitable for tapping steel.

With regard to the size of the hole tapped when different lubricants were used, it was found that the lubricant that produced the least resistance to tapping generally tended to produce the largest tapped hole. For example, when a hole was tapped dry, it would be a most accurate reproduction of the tap as far as size was concerned, but the threads were not clean and smooth, and, of course, the length of life of the tap was reduced. Water used as a lubricant produced good looking threads, but rather high resistance. Stearine oil, which reduced the resistance to tapping to the greatest extent, also produced the largest diameter in the hole.

For tapping aluminum, kerosene is recommended. For tapping cast iron use a strong solution of emulsion; oil has a tendency to make cast-iron chips clog in the flutes, thus preventing the lubricant from reaching the cutting teeth of the tap. For tapping copper, milk is a good lubricant.

Tapping Machines. Machines designed especially for tapping or for drilling and tapping holes are made in quite a variety of designs. Some of these machines are intended for one class of work, like the tapping of nuts, whereas others are adapted to tapping operations of a general nature; there are vertical and horizontal, and single- and multiple-spindle types. Tapping machines also vary in regard to the mechanism for obtaining the forward and reverse motions of the tap spindle and the method of controlling these motions. A common arrangement for obtaining the two motions is by means of a clutch which is interposed between two pulleys revolving in opposite directions and is alternately engaged with these pulleys. The clutch may be controlled by (1) a hand-lever connecting with the clutch; (2) a foot-lever connecting with the clutch; (3) pushing the work and its fixture forward until contact is made with a stop-rod or lever which shifts the clutch for backing out the tap; (4) pushing the work against the tap while tapping and by pulling in the opposite direction for backing out the tap, the clutch being shifted by the direct thrust from the part being tapped and the resulting longitudinal motion of the tap spindles. The latter method is applied only to machines used for the lighter classes of work. The characteristic features of well-designed tapping machines are convenience of control and, for small tapping operations, a sensitive drive that will transmit enough power for operating the tap under normal conditions but not enough to break it in

case the resistance to rotation becomes excessive. See also Nut-tapping Machines.

Tap Relief. See Relief of Taps.

Taps. A tap is an internal thread-cutting tool having teeth which conform to the shape of the thread. Taps may be classified according to the kind of thread with which they are provided, as U. S. Standard thread taps, square thread taps, and Acme thread taps, etc. The most important classification of taps, however, is according to their use.

Hand taps, as the name implies, are intended primarily for tapping holes by hand but are often used in machines. All taps used by hand are not termed "hand" taps as there are many special taps used by hand which are known by specific names.

Tapper taps are used for tapping nuts in tapping machines. They are provided with a long chamfered part on the end of the threaded portion, and a long shank.

Machine nut taps are also used for tapping nuts in tapping machines. This type is designed for more severe duty than the tapper tap and is especially adapted for tapping holes in materials of tough structure. Machine nut taps are chamfered and relieved in a different manner from tapper taps.

Machine screw taps may be either hand taps or machine nut taps, but are known by the name "machine screw tap," because they constitute a class of special taps used for tapping holes for standard machine screw sizes.

Screw machine taps for tapping in the screw machine are provided with shanks fitting either the turret holes of the machine or bushings inserted in these holes. As these taps ordinarily cut threads down to the bottom of the hole, they are provided with a very short chamfer.

Pulley taps are simply a special type of taps used for tapping holes which cannot be reached by ordinary hand taps, as, for instance, the set-screw or oil-cup holes in the hubs of pulleys. They are simply hand taps with a very long shank.

Die taps, also known as long taper die taps, are used for cutting the thread in a die in a single operation from the blank, and are intended to be followed by a sizing hob tap. Die taps are similar to machine nut taps.

Hob taps are used for sizing dies. They are intended only for the final finishing of the thread and can only take a slight chip. They are made to the same dimensions as regular hand taps, but fluted differently.

Pipe taps are used for tapping holes for standard pipe sizes. These taps are taper taps. There is also a special form of pipe tap termed *straight* pipe tap, which is simply a hand tap cor-

responding in diameter and number of threads per inch to standard pipe sizes.

Pipe hobs are similar to pipe taps, but are intended only for sizing pipe dies after the thread has been cut either by a pipe tap or in a lathe.

Boiler taps are used in steam boiler work where a steam-tight fit is required. They are made either straight or tapered. The straight boiler tap is practically only a hand tap.

Mud or washout taps are used in boiler or locomotive work. They are sometimes also called *arch pipe taps*. *Patch bolt taps* are used in boiler and locomotive work. These are taper taps similar to mud or washout taps.

Staybolt taps are used on locomotive boiler work. They are usually provided with a reamer portion preceding the threaded part, and have generally a long threaded portion and a long shank. A special form of staybolt tap is known as a *spindle staybolt tap* which revolves on a central spindle with a taper guide on the front end.

Stove-bolt taps and *carriage-bolt taps* are taps which have derived their names from the uses to which they were originally put. These taps have special forms of threads.

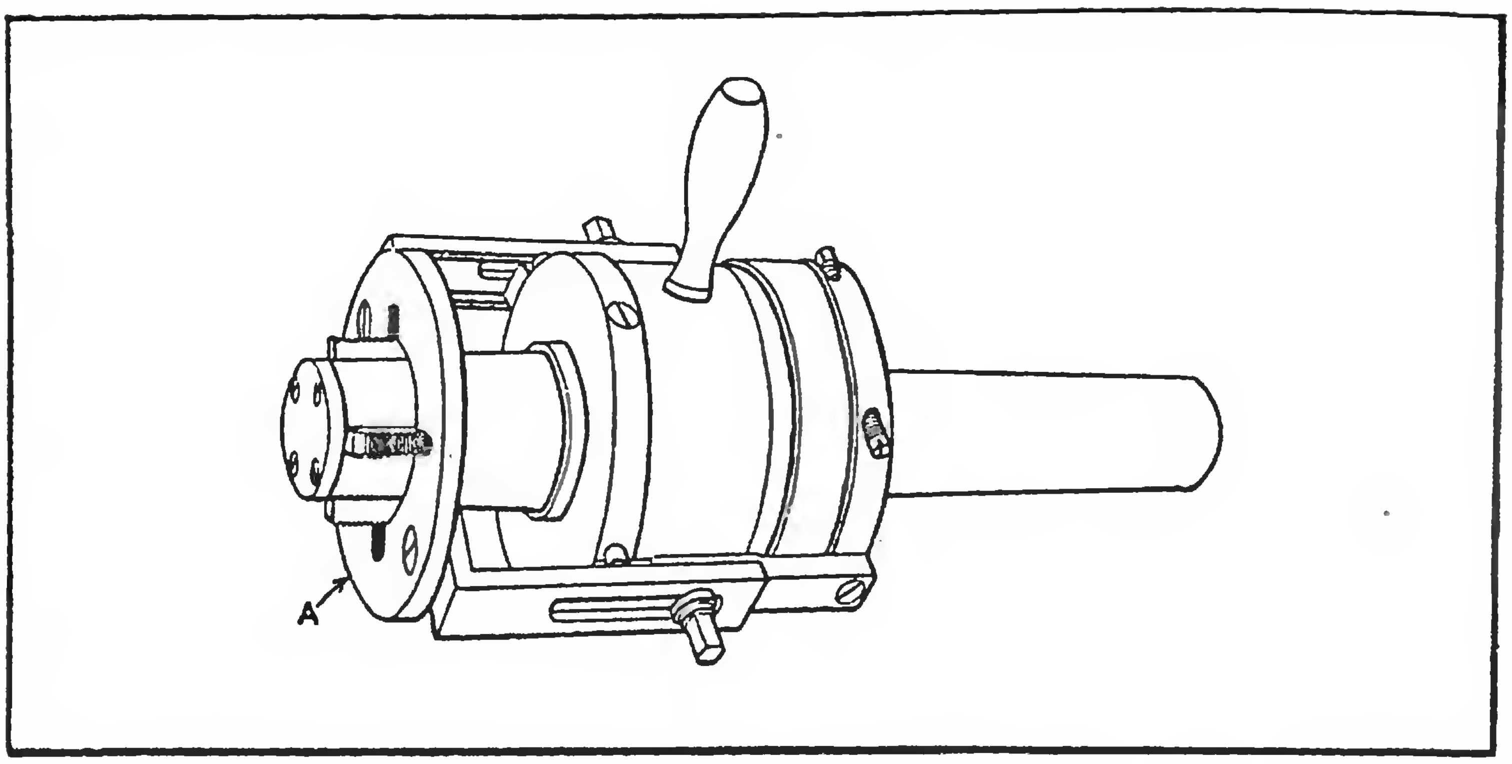
Bit-brace taps differ in no essential from the hand tap on the threaded portion, but are provided with a special shank for use in a bit brace.

Blacksmiths' taper taps are made for general rough threading and are used especially in repair work, where an accurately fitting thread is not required.

Inserted cutter taps may belong to any of the classes mentioned and constitute a separate type only because they are not solid, but have the cutting teeth on blades inserted and held rigidly in a tap body.

Taps, Adjustable. Adjustable taps are made for the purpose of permitting adjustment to a correct standard size. The adjustable tap may either be made from a solid piece, split in a suitable manner to permit adjustment, or it may be provided with inserted blades or cutters, which are so held in the tap body that a slight movement of these blades in the longitudinal direction of the tap moves the cutting points of the thread nearer or farther from the axis of the tap, thus decreasing or increasing the diameter, as the case may be. There are various designs.

Taps, Collapsible. The collapsing tap shown in the accompanying illustration is one of many different designs that are manufactured. These taps are often used in turret lathe practice in place of solid taps. When using this particular style of collapsing tap, the adjustable gage *A* is set for the length of



Collapsing Tap

thread required. When the tap has been fed to this depth, the gage comes into contact with the end of the work, which causes the chasers to collapse automatically. The tool is then withdrawn, after which the chasers are again expanded and locked in position by the handle seen at the side of the holder.

As collapsible taps need not be backed out of the hole at the completion of the thread, this reduces the actual tapping time and naturally increases production. While it does not take quite as long to back a tap out as it does to run it into a hole, due to the faster travel of the machine when reversed, yet, when compared with the instantaneous withdrawal of a collapsible tap, all the time so consumed can be considered as lost. Saving in time and increase of production ranging from 10 to 100 per cent have frequently been shown.

Different Designs of Collapsible Taps: Generally speaking, collapsible taps are made in two chief styles—stationary and rotary. Stationary taps are used on such machines as turret lathes, hand screw machines, certain automatic machines, boring mills, and any machine where the tap is held stationary and the work revolves. Rotary taps are used on drill presses, radial drilling machines, tapping machines, certain automatic machines, or any machine on which the work being tapped is held stationary and the tap revolves.

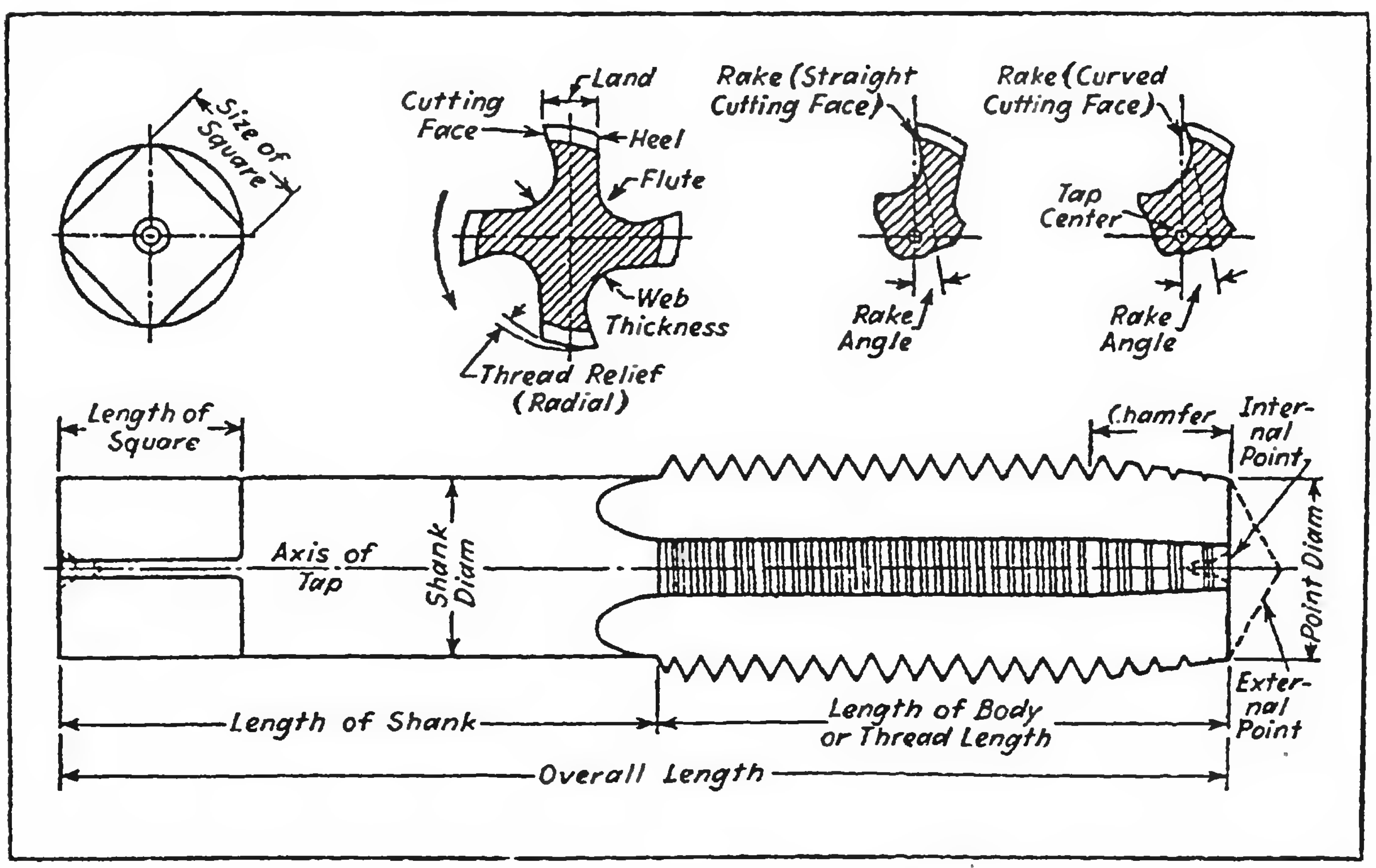
In the stationary style, a lever is employed for expanding the chasers into the cutting position by hand. Frequently this is automatically accomplished by bolting a bar of steel to the turret slide guide, which engages the handle on the backward travel of the turret. The rotary tap can be expanded by arranging a yoke or suitable fixture to the spindle housing to press against a collar

or flange provided for the purpose, as the spindle is backed away or withdrawn from the work. This permits setting the chasers while the tap is in motion. The ordinary method of collapsing the chasers is by means of a tripping collar which is set according to the depth of thread desired, and which comes into contact with the face of the work. This is the type shown in the illustration. Several makes of taps are also on the market in which the chasers are collapsed by what is generally known as the "pull off" method. With these taps the turret is retarded either by hand or by stop-screws, and the action of the chasers in pulling on the threads already cut operates a cam, which collapses the chasers.

Taps, Die. See Die Taps.

Taps, Ground. A notable development in tap manufacture consists in grinding the taps after hardening. The grinding process serves to correct the distortion due to the hardening process and it also leaves the tap with keen cutting edges. The advantages of grinding include accuracy of shape or thread form, accurate lead, as accurate a diameter as is necessary to meet commercial requirements, and the effective use of high-speed steel.

Ground taps are made from high-speed steel, and the grinding process after heat-treatment, makes it possible to harden such taps at the high temperatures required to get best results with steels of this class. There are two general methods of making



Illustrations showing the Meaning of Terms Commonly Applied to Taps

ground taps. One plan is to machine the tap thread and then correct it after hardening by grinding off the slight amount that has been left for this purpose. The other method is to harden the unthreaded tap blank and then form the entire thread by the grinding operation. It is claimed that this process of grinding "from the solid" permits the nearest approach to the ideal heat-treatment of steel. Ground taps not only provide means of producing accurately threaded holes, but they are capable of exceptionally large production per tap, owing to the use of the properly heat-treated high-speed steel taps which have keen cutting edges. Some ground taps have been made from carbon steel, but the consensus of opinion is that this refined method of finishing taps should only be applied to steels of the high-speed class in order to obtain the best results. See also Tapped Hole Accuracy.

Taps, Hand. See Hand Taps.

Tap Terms and Definitions. The accompanying illustration shows the meaning of some commonly used tap terms. Definitions of these and other terms follow:

Back Taper: A slight relief on the body of the tap axially, which makes the pitch diameter of the thread near the shank somewhat smaller than that at the point.

Base of Thread: The bottom section of a thread; the greatest section between the two adjacent roots.

Chamfer: The tapering of the end of the tap by cutting away the crest of the first few threads to distribute the cutting action over several teeth. It also acts as a guide in starting the tap into a hole.

Crest: The top surface joining the two sides of a thread.

Flute: That portion cut away between the lands.

Helix Angle of Flute: The flutes of taps are sometimes cut helically instead of straight to either pull the chips out of the hole or to bridge a gap such as a keyway. The helix angle is the angle made by the flute with the axis of the tap.

Interrupted Thread: Applied to taps with an odd number of flutes so that every other tooth along the helix is removed. This eliminates friction and causes thicker chips per tooth to be taken and is sometimes used for relatively large taps in tough metals.

Land: That portion of a thread not cut away by the flutes.

Rake: Hook or undercut on the face of the teeth. When the faces are radial, the rake angle is zero. The rake angle is positive when the outer end of the teeth is ahead of the bottom. The rake angle is varied for different materials and conditions of tapping.

Relief: The condition whereby metal is removed from behind the cutting edge to produce clearance and reduce friction. Taps

should have the chamfer relieved and may or may not have relief in the angle and on the major diameter of the threads.

Task Time. The predetermined time in which a given job should be performed under the bonus wage system of payment is called the task time.

Taylor-White Process. This process of hardening high-speed steel is, briefly, as follows: The first step, commonly known as the "high-heat treatment," is effected by heating the tool slowly to 1500 degrees F., and then rapidly from that temperature to just below the melting point, after which the tool is quickly cooled below 1550 degrees F. At this point, the cooling is continued either fast or slow to the temperature of the air. It is important to avoid any increase of temperature during the cooling period. The second, or "low-heat treatment," consists in reheating a tool which has had the high-heat treatment to a temperature somewhere between 700 and 1240 degrees F., preferably in a lead bath, for a period of five minutes. The tool is then cooled to the temperature of the air either rapidly or slowly.

As there are many high-speed steels on the market, the heat treatment recommended by the steel manufacturer in each case should be applied.

T-Bolt. See T-slot.

Teat Drill. The cutting edges of a teat drill are at right angles to the axis, and in the center there is a small teat of pyramid shape which leads the drill and holds it in position. This form is used for squaring the bottoms of holes made by ordinary twist drills or for drilling the entire hole, especially if it is not very deep and a square bottom is required. For instance, when drilling holes to form clearance spaces at the end of a keyseat, preparatory to cutting it out by planing or chipping, the teat drill is commonly used.

Tee. A tee is a pipe fitting, either cast or wrought, that has one side outlet at right angles to the run; that is, a single outlet branch pipe. A *cross-over tee* is made along lines similar to a cross-over, but having at one end two openings in a tee-head the plane of which is at right angles to the plane of the cross-over bend. A *union tee* has a male or female union at the connection on one end of the run. A *service tee* has an inside thread on one end and on the branch, but an outside thread on the other end of the run; it is also known as a *street tee.* A *double-sweep tee* is made with easy curves between body and branch, i.e., the center of the curve between the run and branch lies outside the body.

Tee Section. The standard structural section known as a tee has a T shape. See Structural Shapes.

Teflon. A fluorine-containing, chemical- and heat-resistant plastic with a dielectric strength of 1,500 volts per mil. Although it is a thermoplastic it does not soften appreciably until it has reached a temperature of about 700 degrees F. The material begins to decompose at temperatures above 300 degrees F. and since one of the products of decomposition is a harmful fluorine-containing gas, use of the material at this high temperature should be accompanied by adequate ventilation. Teflon is wax-like, has self-lubricating properties, and has a specific gravity of 2.2. Its uses include: pressure-valve seals, gaskets, and electrical insulation materials.

Telegraph. Credit for the invention of the electric telegraph is ordinarily given to Prof. Samuel F. B. Morse of Mass., although this invention, like many other epoch-making inventions, was not the work of one man. The development of the battery, which was an important element in developing the electric telegraph, began with Galvani in 1790, and Volta in 1800, and in 1836 the Daniell battery was invented by Prof. Daniell of London. The fact that electricity could be transmitted through a metallic conductor had been observed many years prior to the invention of the electric telegraph; moreover, in 1837 Prof. Steinheil of Munich discovered the practicability of using the earth as the return section of an electrical circuit. The electromagnet, which constitutes such an important part of the electric telegraph, was developed chiefly by Prof. Joseph Henry of Princeton, N. J., although the underlying principle of the electromagnet was first discovered in 1819 by Prof. Oersted of Copenhagen. The Morse register and alphabetical code was the invention of Prof. Morse, and the first United States patent was issued in 1840. The first instrument was designed to draw on a strip of paper zigzag lines, thus providing a visible code. In 1844 a receiving register was adopted which recorded on a paper ribbon a series of dots and dashes, instead of zigzag markings.

Telephone. Prof. Alexander Graham Bell, according to decisions of the Patent Office and courts, was the first inventor of a practical telephone. The first patent was awarded to Prof. Bell in 1876 and the second patent in 1877. Philip Reis in 1861 devised an electric telephone that transmitted musical tones. Various inventors claimed credit for the invention of the telephone and perhaps the most important contestant was Elisha Gray who filed a caveat in the Patent Office upon the same day that Prof. Bell made his application. In the contest which followed

with Gray and other inventors, the Patent Office decided that the first practical form of telephone was that of Prof. Bell's, and this decision was later sustained by the courts.

Tellurium. Tellurium is closely related chemically to selenium, and while in appearance wholly metallic, it is not classed among the metals. It is brittle and crystalline and has a silver-white color which is similar to that of unoxidized zinc, and is so soft that it can be scratched by the finger nail. The specific gravity of tellurium is 6.25, the atomic weight, 127.5, and its weight per cubic inch is 0.226 pound. It melts at 452 degrees C. (846 degrees F.) and boils at 478 degrees C. (892 degrees F.). Tellurium is practically a non-conductor of electricity. It has been used for coloring glass, to which it gives a peculiar reddish tint.

Temperature, Absolute. See Absolute Temperature.

Temperature Cones. See Seger Temperature Cones.

Temperatures, Critical. See Critical Temperatures.

Temperatures, Ignition. See Ignition Temperatures.

Temperature Standards for Gages. Inasmuch as the size of a gage varies somewhat with temperature changes, it is evident that the size should be based upon some standard temperature. In the standardization of precision gages for industrial use, 68 degrees F. has been adopted generally in the United States during recent years as the standard temperature, because it is the common or average working temperature to which gages are ordinarily subjected in practice. Formerly 62 degrees F. was the temperature used for precision gage standardization, as this is the temperature, approximately, at which the standard yard bar is at the correct length; but a temperature of 68 degrees F. is the generally used working standard for the calibration of industrial gages. This temperature not only conforms to average working temperatures, but it has been widely employed for many other physical tests, and moreover, it is the exact equivalent of 20 degrees C.

This same temperature of 20 degrees C., or 68 degrees F., has been adopted as the standard for gage work and other industrial measuring instruments, by engineering standardization bodies in Germany, Holland, Sweden, and Switzerland. In Great Britain the temperature of 62 degrees F., which applies to the fundamental standard yard bar, is also employed as the basis for industrial gage and instrument calibration.

Tempering. The object of tempering, or "drawing," is to reduce the brittleness in hardened steel, and to remove the internal

strains caused by the sudden cooling in the quenching bath. The tempering process consists in heating the piece of work, by various means, to a certain temperature, and cooling it. The degree of heat to which the tool to be tempered is heated determines the degree of toughness and also the degree of softness. Hardened steel is tempered in order to make it less brittle, but unfortunately the tempering process also softens the steel, to some extent. If it were possible to temper steel so as to produce greater toughness and, at the same time, retain the extreme hardness, the ideal condition would be obtained. That hardness and brittleness are not necessarily synonymous may be seen in the case of cast iron, which is very brittle, but not very hard. On the other hand, there are some alloy steels that may be made very hard and at the same time very tough. The object of tempering steel is to reduce the brittleness; that the hardness is simultaneously reduced cannot, unfortunately, be avoided.

The modern method of tempering, especially in quantity, is to heat the hardened parts to the required temperature in a bath of molten lead, heated oil, or other liquids; the parts are then removed from the bath and quenched. The bath method makes it possible to heat the work uniformly, and to a given temperature, within close limits, because the temperature of the bath may readily be determined. While oil is the most widely used medium for tempering tools in quantities, other means and methods are employed, especially by those who have tools in small quantities to temper when the expense of installing and running an oil tempering furnace would not be warranted.

Tenite. A thermoplastic molding material obtainable both in sheet and granular form. Available in all colors and in sheets in thicknesses from 3/16 to 1 inch and in pieces as large as 20 by 25 inches. Has unusual strength. May be used for all classes of molded plastics, especially for parts that may be subjected to temperatures up to 160 degrees F. and that must resist vegetable or mineral oils.

Tensile Test. Tensile tests of steel, or other materials used in building machines, buildings or other structures, are made with a powerful machine which pulls the standard test specimen apart and indicates the amount of force required. The objects in making tensile tests are: to determine the elastic limit, the ultimate strength, the elongation, the reduction in area, and the appearance of the fracture.

Tensile Test Specimens. In testing the tensile strength of different materials in machines designed for this purpose, the piece subjected to the test should conform to a standard shape

and size so that tests made in different plants or laboratories will represent uniform conditions and the resulting test data will be comparable. The forms and sizes of test specimens for different materials are included in the recommendations of the American Society for Testing Materials.

Plate Material: One form of test specimen is used for plate material having a thickness of ¼ inch or more. The thickness for the test specimen equals the thickness of the material. A rectangular strip about 2 inches wide at the gripped ends has, between these ends, a reduced parallel section 1½ inches wide and not less than 9 inches long. This parallel section includes what is known as the "gage length" for measuring elongation after fracture.

Sheet Metals: For ferrous and non-ferrous sheet metals, the gripped ends are about 11/16 inch wide, the reduced parallel section has a minimum length of 2¼ inches, and a gage length of 2 inches. The width of this reduced section is 0.500 inch with certain tolerances. This test specimen is applied to plates, sheets, strips, etc., varying in thickness from 0.01 to 0.25 inch. In testing tubing, the specimen may be cut from a section of the tube.

Test Specimen for General Use: The tension test specimen recommended for general use in testing metals is cylindrical in form. The ends for gripping may be plain-shouldered or they may be threaded. The plain-shouldered ends have a diameter of ⅞ inch and the threaded ends a diameter of ¾ inch. The reduced section between these ends has a nominal diameter of ½ inch, and the gage length in this parallel section is 2 inches. Complete specifications for these various test specimens are covered by the A.S.T.M. designation E8-36.

Tension Scales for Belts. The tension of belts used for the transmission of power should be varied according to the length, width, and thickness of the belt. When a belt is kept at the proper tension, its life is materially increased, and the cost of maintenance and repairs is greatly reduced. A belt should not only have the proper initial tension at the time it is put up, but this tension should be maintained. If a belt is too tight, there is a constant waste of power due to excessive friction in the bearings, and if it is too loose, a loss in efficiency from slippage results; both conditions tend to shorten the life of the belt. A belt tension scale has been designed for testing the tension while a belt is in position on the pulleys. The scale is placed on the belt and a handle is turned, thus causing tension to be applied to the belt by means of a spring contained within the scale. The tension of the belt is indicated by graduations which show whether or not the belt requires tightening, and, if so, how much should be cut out of the belt.

Terminal Pressure. The terminal pressure is the pressure in the cylinder of a steam engine at the time release occurs, and depends upon the initial pressure, the ratio of expansion, and the amount of cylinder condensation.

The terminal pressure of an air compressor is the pressure to which the air is compressed.

Ternary Alloy. This is an alloy consisting of three elements. When the term refers to steel, it denotes a steel which contains two alloying elements in addition to iron; since carbon is always present, it is one of these elements. The third element may be nickel, chromium, manganese, tungsten, molybdenum, titanium, or any other element that is alloyed to give the steel some special property.

Terne-Plate. Terne-plate differs from tin-plate in that the latter is sheet steel coated with commercially pure tin, while terne-plate or roofing tin consists of sheet steel coated with an alloy of tin and lead. This alloy is usually composed of 32 per cent of tin and 68 per cent of lead; 26 per cent of tin and 74 per cent of lead; or 16 per cent of tin and 84 per cent of lead. Coating the steel with this alloy increases its weight about 20 per cent. Terne-plates are made in sizes of 10 by 14 inches, and in multiples of that measure. The sizes generally used are 14 by 20 inches and 20 by 28 inches. The plates that are coated with an alloy containing from 26 to 32 per cent of tin are generally known as No. 1 terne, while those containing 16 per cent of tin are known as No. 2 terne.

Test Indicators. Test indicators are extensively used in connection with the repair or erection of machinery, for detecting any lack of parallelism between surfaces, in inspection departments, and for testing the accuracy of rotating parts (such as spindles or arbors) in connection with general machine shop and tool-room work. Indicators of the dial type show the variations in measurement or alignment by the movement of a hand relative to a graduated dial. Other indicators, instead of having a graduated dial, are equipped with a long indicating hand or "finger" which is so connected with the contact point that movements of the latter are considerably magnified.

Tests, Impact. See Impact Tests.

Tetrabasic Acid. In chemistry, this is an acid which has four atoms of hydrogen in each molecule replaceable by a metal.

Thallium. Thallium is a rare metallic element with a specific gravity of 11.85 and a melting point of 300 degrees C. It

is used in white bearing alloys as it imparts strength and resistance to deformation. Its salts are highly poisonous, which is why its sulphide is used as a rat poison.

Therbligs. Frank and Lillian Gilbreth, the so-called parents of motion study, developed a system of dividing all motions into a number of basic elements that apply to any work situation. They coined the word "therblig" (a variation of Gilbreth spelled backwards) to refer to any one of 18 divisions of accomplishment. Some therbligs are: search, find, select, grasp, transport load, position, assemble, and use.

Thermal Unit. This is a unit for measuring quantity of heat, being the amount of heat required for raising the temperature of a certain weight of water one degree on some thermometer scale. In the English system, the British thermal unit is the quantity of heat required to raise the temperature of one pound of pure water one degree F. In the metric system, the French thermal unit, or *calorie*, is the quantity of heat required to raise the temperature of one kilogram of pure water one degree C.

Thermit Welding. The thermit process of welding metals is effected by pouring superheated thermit steel around the parts to be united. Thermit is a mixture of finely divided aluminum and iron oxide. This mixture is placed in a crucible and the steel is produced by igniting the thermit in one spot by means of a special powder, which generates the intense heat necessary to start the chemical reaction. When the reaction is once started, it continues throughout the entire mass, the oxygen of the iron being taken up by the aluminum (which has a strong affinity for it) producing aluminum oxide (or slag) and superheated thermit steel. Ordinarily, the reaction requires from 35 seconds to one minute, depending upon the amount of thermit used. As soon as it ceases, the steel sinks to the bottom of the crucible and is tapped into a mold surrounding the parts to be welded. As the temperature of the steel is about 5400 degrees F., it fuses and amalgamates with the broken sections, thus forming a homogeneous weld. It is necessary to preheat the sections to be welded before pouring, to prevent chilling the steel. The principal steps of the welding operation are: to clean the sections to be welded; remove enough metal at the fracture to provide for a free flow of thermit steel; align the broken members and surround them with a mold to retain the steel; preheat by means of a gasoline torch to prevent chilling the steel; ignite the thermit and tap the molten steel into the mold. This process is especially applicable to the welding of large sections. It has been used for welding locomotive frames, rudder- and stern-posts of ships, crankshafts, and

heavy repair work, in general. One of the great advantages of the thermit process is that broken parts can usually be welded in place by simply removing parts that would interfere with the application of a suitable mold.

Thermochemistry. Thermochemistry is that part of the science of chemistry which deals with the heat produced or absorbed by chemical reactions. Reactions in which heat is evolved are termed *exothermic;* those in which heat is absorbed are called *endothermic.*

Thermocouple. When two dissimilar metals are placed in contact with one another and are heated or cooled at their point of contact, an electromotive force is produced which varies with the difference in temperature between the point of contact and the opposite ends of the metals, which may or may not be joined. Such a device is called a thermocouple. The requirements of a good thermocouple are: 1. A high melting point of the elements. 2. The property of generating as large an electromotive force as possible, and an electromotive force which will increase as nearly as possible in direct proportion to rise in temperature, in order to obtain a uniform measuring scale. 3. Constancy of couples throughout their life. The use of different pairs of metals in thermocouples results in different electromotive forces being produced.

There are two general classes of metals used for the thermocouples, known as base metals and rare metals, the former being the more widely used. The latter are much more expensive, but they are adapted to higher temperatures. Base metal couples are ordinarily used for temperature measurement in conjunction with the heat-treatment of carbon steels, but rare metal couples are often used in preference in the case of high-speed steels. Base metal couples are usually made either of some nickel alloy or of iron-constantan, and rare metal couples of platinum in conjunction with a platinum alloy. The base metal couples have several advantages, especially as applied to pyrometers for use in heat-treating plants. See also Pyrometer, Thermocouple.

Thermoil-Granodine. A coating material developed to prevent wear and rust of machine parts. Applied by immersing the machine parts, after thorough cleaning, in a boiling solution of the coating material. The solution transforms the surface into a layer of iron and manganese phosphates, which becomes an integral part of the metal beneath. Suitable for treating automobile engine parts, such as pistons, valves, and camshafts; gears; and any machine parts having bearing surfaces.

Thermometer. Thermometers are used only for measuring comparatively low temperatures, generally not above 200 or

300 degrees F. The instruments used for measuring the degree of heat at higher temperatures are known as *pyrometers*. There are three thermometer scales in general use: The Fahrenheit (F.), which is generally used in the English speaking countries; the Centigrade (C.) or Celsius, which is used in several continental countries and in scientific work; and the Reaumur (R.), which is used to some extent on the European continent, notably in Germany.

In the Fahrenheit thermometer, the freezing point of water is marked at 32 degrees on the scale and the boiling point at 212 degrees. (Boiling point when atmospheric pressure is 14.7 pounds per square inch or at sea level.) The distance between these two points is divided into 180 degrees. On the Centigrade scale, the freezing point of water is at 0 degrees and the boiling point at 100 degrees. On the Reaumur scale, the freezing point is at 0 degrees and the boiling point at 80 degrees.

To find the degrees Centigrade subtract 32 from the degrees Fahrenheit, multiply the remainder by 5 and divide the product by 9. To find the degrees Fahrenheit multiply the degrees Centigrade by 9, divide the product by 5, and add 32 to quotient.

Thermometer for High Temperatures: A thermometer capable of temperature readings up to 1000 degrees C. (1832 degrees F.) uses the element gallium, which is sealed in a capillary tube of fused quartz of uniform bore. Gallium melts at 29.7 degrees C. (about 85 degrees F.) and boils at approximately 1700 degrees C. (about 3100 degrees F.).

Thermostat. A thermostat is a device consisting of a thermally responsive element and one or more electrical contacts which opens and closes one or more circuits in response to changes in temperature. There are four main classes of thermostats: (1) Those which depend upon the movement of a simple bimetal element; (2) those which depend upon the differential movement between two elements of different metals; (3) those which depend upon the expansion and the contraction of a liquid or vapor in a hydraulic system; and (4) those which depend upon the movement of mercury in a capillary tube.

Thomas-Gilchrist Process. This is a method for converting pig iron into steel by the Bessemer process. See Bessemer Process.

Thread Angle. The standard angle of a thread having sloping sides is always the angle included between the sides measured in a plane intersecting the axis. This standard angle for each screw thread system is always the same regardless of the pitch or number of threads per inch. For example, the angle of American Standard screw threads is 60 degrees in all cases.

Lead Angle: Another angle pertaining to screw threads is known as the lead angle. This angle indicates the inclination of the thread relative to a plane perpendicular to the axis of the screw. The cotangent of the lead angle, say, at the pitch diameter, equals the pitch circumference divided by lead of thread. The lead angle of a given screw thread increases from the crest down to the root of the thread, and the intermediate lead angle at the pitch diameter is the one ordinarily required. For example, in milling a thread, the cutter is inclined to suit this intermediate lead angle so that its plane of rotation will be in alignment with the groove of the thread.

Thread Chasers. A chaser is a form of threading tool having a number of teeth instead of a single point like the threading tools commonly used for screw cutting in the engine lathe, although the term "thread chasing" is often used to indicate the cutting of a thread with a single-point tool. The two general classes of chasers (exclusive of those used in dies) are hand chasers and threading tool chasers. The former are hand-controlled, and the latter are rigidly held in a tool-holder and used like an ordinary lathe threading tool. When a hand chaser is in use, the cutting end is supported by some form of rest held in the toolpost. These hand chasers are convenient for truing up battered threads or for reducing the size of a part which has been threaded by either a die or a single-point tool. Tools of this kind are especially adapted for brass work. The chaser has teeth spaced to correspond to the pitch of the thread. This form of tool can be applied to the work quickly and without gearing the lathe for a thread-cutting operation.

Chasers Held in Tool-holder: Threading tool chasers which are held rigidly in the tool-holder are used practically the same as a single-point tool, the lathe being geared for traversing the tool along the work in order to control the lead of the thread. Tools of this kind cut threads rapidly and may be used for roughing out threads preparatory to finishing them with a regular single-point tool. Many screw threads are also finished completely with chasers of this type, although they are not adapted for extremely accurate work unless the teeth are ground after hardening, because the pitch of the chaser teeth is affected more or less by the hardening operation. The pitch of the chaser teeth does not always equal the pitch of the thread to be cut. For instance, a chaser may have a pitch double that of the screw thread. Every alternate groove is engaged, but as the lathe is geared for the pitch of thread to be cut, each tooth of the chaser follows the thread groove the same as though it were a single tool. Chasers are sometimes made in this way for cutting very fine threads, because larger and stronger teeth are obtained.

Thread-Chasing Attachments. Most threading operations in the turret lathe are done by using taps and dies, but, for some classes of work, thread-chasing attachments are used. Such attachments cover a wide range of diameters and may be used, either because the work is too large for a tap or die or because the number of parts required is not large enough to warrant the purchase of special taps and dies. Another advantage of the thread-chasing attachment is that it enables a screw thread to be produced which is known to be true with other cuts that have been taken at the same setting of the work. One type of attachment consists of a reciprocating cutter bar which is carried by a holder that is bolted to the turret. Motion is imparted to the cutter bar from the main spindle of the machine through gearing and a splined transmission shaft, which enables the turret to be indexed without interfering with the attachment. Another form of chasing attachment consists of a leader or short lead-screw which is mounted upon the feed-rod of the machine, and a brass follower that is engaged or disengaged by a lever pivoted in a bracket bolted to the carriage apron. A bar carrying a single-point chasing cutter is held in a holder clamped onto the turret.

Thread Chasing Dial. A thread chasing dial or indicator is a simple device which is attached to the carriage of a lathe and used when cutting threads to enable the operator to engage the carriage with the lead-screw at the proper time, so that the thread tool will follow the original or first cut. The chasing dial consists of a graduated dial and a worm-wheel which meshes with the lead-screw so that the dial is revolved by the lead-screw when the carriage is stationary, and, when the carriage is moved by the screw, the dial remains stationary. The number of teeth in the worm-wheel driving the dial is some multiple of the number of threads per inch of the lead-screw, and the number of teeth in the worm-wheel, divided by the pitch of the screw, equals the number of graduations on the dial. For example, if the lead-screw has six threads per inch, the worm-wheel could have twenty-four teeth, in which case the dial would have four divisions, each representing an inch of carriage travel, and, by subdividing the dial into eighths each line would correspond to ½ inch of travel. The dial, therefore, would enable the carriage to be engaged with the lead-screw at points equal to a travel of one-half inch. If the thread being cut had nine threads per inch, or any other odd number, the tool would only coincide with the thread at points 1 inch apart. Therefore, the carriage can only be engaged when one of the four graduations representing an inch of travel is opposite the zero mark or arrow, when cutting odd threads; whereas even numbers can be "caught" by using

any one of the eight lines, assuming that the dial were graduated as described.

Thread-Cutting Attachments for Large Leads. When a lathe is used for cutting a screw thread of exceptionally large lead, or steep pitch, the change-gear mechanism may be subjected to excessive stresses if the power for traversing the carriage along the bed is transmitted from the lathe spindle to the lead-screw in the usual manner. This is due to the unusual distance that the carriage must move along the bed per revolution of the work in order to obtain a large lead. For instance, if the lead is such that the lead-screw must be revolved quite rapidly to move the carriage and tool a distance equal to the lead of the thread, each time the spindle makes one revolution, the teeth, especially on the first gear of the train, may be broken as a result of the excessive stress. One method of avoiding trouble of this kind is to apply power directly to the lead-screw, instead of to the spindle; motion is then transmitted from the high-speed member of the gear train to the low-speed member, as the lead-screw drives the spindle and the load on the gear teeth is reduced.

Special Drive from Cone Pulley: Another method of overcoming this difficulty on a lathe having a cone pulley is by driving the lead-screw from the gear on the cone pulley, special gearing being used to transmit the motion.

Special Lead-screw for Coarse Pitches: A special lead-screw for cutting threads of large lead is applied to some lathes. With one arrangement, this auxiliary lead-screw extends along the rear side of the bed, and when in use the back-gearing of the headstock is engaged; the drive is then from the large back-gear, through change-gearing, to the special lead-screw. The lathe is equipped with the regular quick-change gear mechanism and a lead-screw at the front for ordinary thread-cutting operations.

Speed-Reducing Faceplate: The speed-reducing faceplate simply reduces the speed of the work so that the lead of the thread is increased proportionately. Motion is transmitted from the headstock spindle to the work-driving plate, through a planetary gear train which, in one design, reduces the work speed in the ratio of 6 to 1, relative to the headstock spindle and the lead-screw; consequently, it is possible to cut threads six times coarser in lead than are indicated on the instruction plate attached to the headstock.

Thread-Cutting Change-Gears. See Change-gears for Thread-cutting.

Thread-Cutting Dies. See Dies for Thread-cutting.

Thread-Cutting Methods. The two general methods of forming screw threads may be defined as the cutting method and the

rolling or displacement method. The cutting methods as applied to external threads are briefly as follows:

1. By taking a number of successive cuts with a single-point tool that is traversed along the part to be threaded at a rate per revolution of the work depending upon the lead of the thread. (Common method of cutting screw threads in the engine lathe.)

2. By taking successive cuts with a multiple-point tool or chaser of the type used to some extent in conjunction with the engine lathe and on lathes of the Fox or monitor types.

3. By using a tool of the die class, which usually has four or more multiple-point cutting edges or chasers and generally finishes the thread in one cut or passage of the tool.

4. By a single rotating milling cutter, which forms the thread groove as either the cutter or the work is traversed axially at a rate depending upon the thread lead.

5. By a multiple rotating milling cutter which completes a thread in approximately one revolution of the work.

6. By a multiple rotating cutter which also has a planetary rotating movement about the work which is held stationary. See Planamilling and Planathreading.

7. By a grinding wheel having its edge shaped to conform to the groove of the screw thread.

8. By a multi-edged grinding wheel which, within certain limits as to thread length, will grind the complete thread in practically one revolution of the work.

Internal screw threads, or those in holes, may or may not be produced by the same general method that is applied to external work. There are three commercial methods of importance, namely:

1. By the use of a single-point traversing tool in the engine lathe or a multiple-point chaser in some cases.

2. By means of a tap which, in machine tapping, usually finishes the thread in one cut or passage of the tool.

3. By a rotating milling cutter of either the single or the multiple type.

Dies operated by hand are frequently used for small and medium-sized parts, especially when accuracy as to the lead of the thread and its relation to the screw axis is not essential and comparatively few parts need to be threaded at a time. When a large number of pieces must be threaded, power-driven machines equipped with dies are commonly employed. If the operation is simply that of threading the ends of bolts, studs, rods, etc., a "bolt cutter" would generally be used, but if cutting the thread were only one of several other operations necessary to complete the work, the thread would probably be cut in the same machine performing the additional operations. For instance,

parts are threaded in turret lathes and automatic screw machines by means of dies and in conjunction with other operations. When screws are required which must be accurate as to the pitch or lead of the thread, and be true relative to the axis of the work, a lathe is generally used; lathes are also employed, ordinarily, when the threaded part is comparatively long and large in diameter. Many threads which formerly were cut in the lathe are now produced by the milling process in special thread-milling machines. The method often depends upon the equipment at hand and the number of parts to be threaded. Very precise threads may be produced by grinding.

Thread, "Drunken." See "Drunken" Thread.

Thread Generating Machine. A machine known as a thread generator for generating threads on worms, hobs and similar parts operates on the molding-generating principle, using a helical gear-shaper cutter. The work rotates on an axis at right angles to that of the cutter, and the cutter rotates in unison with the work; that is, the work and cutter are geared together in relation to the number of teeth in the cutter and the number of threads on the worm. The cutter is carried in a head mounted on a slide that is traversed longitudinally along the work, and as the cutter is rolled in mesh with the work, it produces threads by the generating process.

Thread Grinding. Thread grinding is applied both in the manufacture of duplicate parts and also in connection with precision thread work in the tool-room.

Single-edged Grinding Wheel: In grinding a thread, the general practice in the United States is to use a large grinding wheel (for external threads) having a diameter of possibly 18 to 20 inches. The width may be 5/16 or ⅜ inch. The face or edge of this comparatively narrow wheel is accurately formed to the cross-sectional shape of the thread to be ground. The thread is ground to the correct shape and lead by traversing it relative to the grinding wheel. This traversing movement, which is equivalent to the lead of the screw thread for each of its revolutions, is obtained from a lead-screw. On one type of thread grinder, this lead-screw is attached directly to the work-spindle and has the same lead as the screw thread to be ground; hence, there is a separate lead-screw for each different lead of thread to be ground. On another design of machine, the lead-screw arrangement is similar to that on a lathe in that the required lead on the ground thread is obtained by selection of the proper change gears. The grinding wheel may have a surface speed of 7000 feet a minute, whereas the work speed may range from 3 to 10 feet per minute. The grinding wheel is inclined to suit the helix

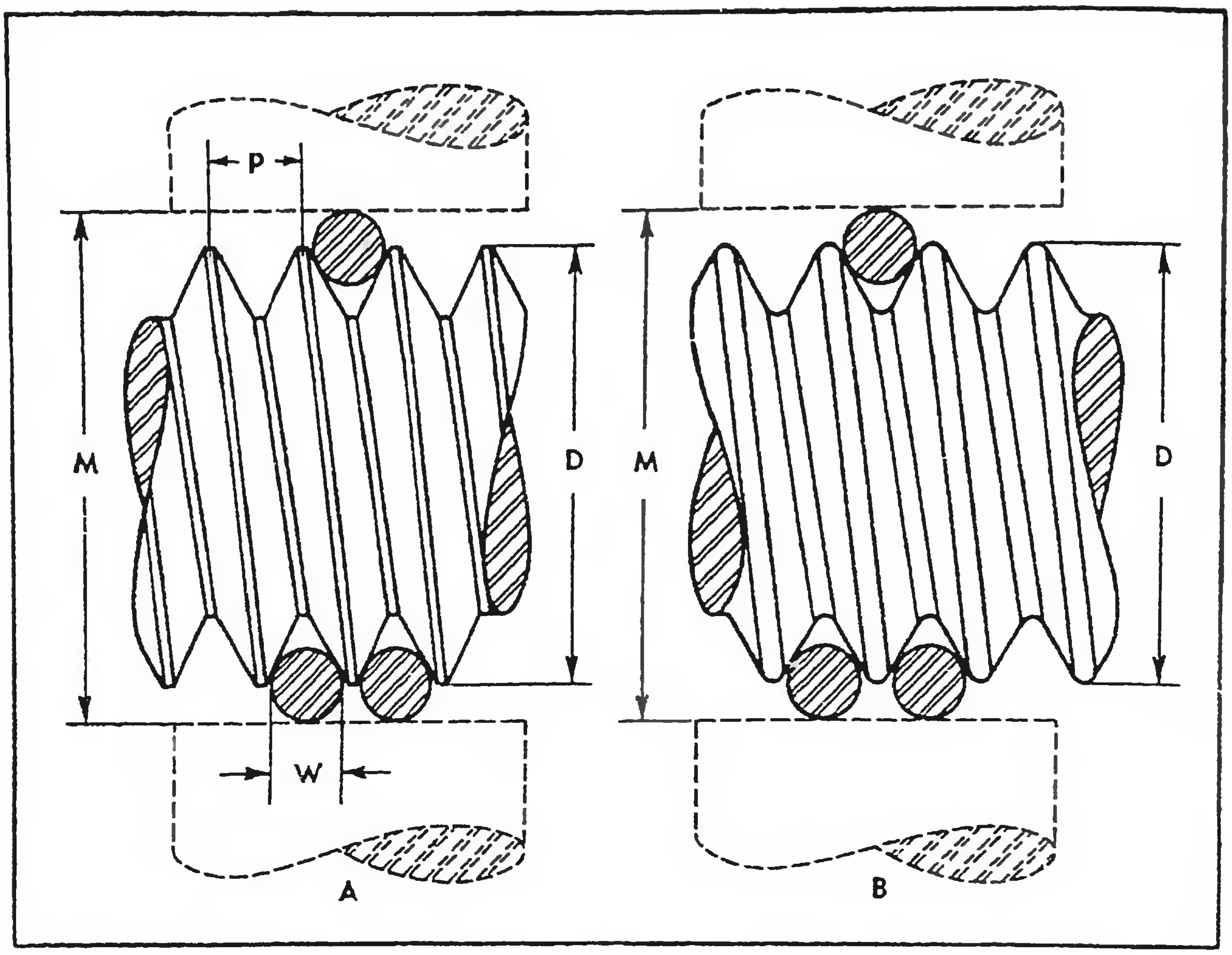
angle of the thread and either right- or left-hand threads may be ground. Provision is also made for grinding multiple threads and for relieving taps and hobs. The wheel shape is accurately maintained by means of diamond truing tools. On one type of machine, this truing is done automatically and the grinding wheel is also adjusted automatically to compensate for whatever slight reduction in wheel size may result from the truing operation.

An internal thread may also be ground with a single-edged wheel. The operation is the same in principle as external thread grinding. The single-edged wheel is used whenever the highest precision is required, grinding the work either from the solid or as a finishing operation.

Grinding "from the Solid": On some classes of work, the entire thread is formed by grinding "from the solid," especially if the time required is less than would be needed for a rough thread-cutting operation followed by finish-grinding after hardening. Grinding threads from the solid is applied to the finer pitches. In some plants, threads with pitches up to about 1/16 inch are always ground by this method.

Multi-edged Grinding Wheel: An entire screw thread, if not too long, may be ground completely in one revolution by using a multi-edged type of grinding wheel. The face of this wheel is formed of a series of annular thread-shaped ridges so that it is practically a number of wheels combined in one. The principle is the same as that of milling screw threads by the multiple-cutter method. If the length of the thread to be ground is less than the width of the wheel, it is possible to complete the grinding in practically one work revolution as in thread milling. A grinding wheel having a width of, say, 2½ inches, is provided with annual ridges or threads across its entire width. The wheel is fed in to the thread depth, and, while the work makes one single revolution, the wheel moves axially a distance equal to the thread lead along the face of the work. Most threads which require grinding are not longer than the width of the wheel; hence, the thread is completed by one turn of the work.

If the thread is longer than the wheel width, one method is to grind part of the thread and then shift the wheel axially one or more times for grinding the remaining part. For example, with a wheel 2½ inches in width, a thread approximately 12 inches long might be ground in five successive steps. A second method is that of using a multi-edged tapering wheel which is fed axially along the work. The taper is to distribute the work of grinding over the different edges or ridges as the wheel feeds along.



A Precision Method of Checking the Pitch Diameter of a Screw Thread

Thread Hobbing. A hob is sometimes used in conjunction with a gear-hobbing machine for milling multiple screw threads. A hob used for this purpose has teeth which lie along a helical path, like a hob intended for cutting spur or helical gears, and it must be geared to revolve with the work at a definite speed ratio, the same as when hobbing a gear. The hobbing method is particularly efficient for cutting worms having several threads, because the hob finishes the different threads simultaneously.

Threading Attachments, Coarse. See Coarse Threading Attachments.

Thread Measurement, Three-Wire Method. The pitch diameter of a screw thread may be checked very accurately by what is known as the "three-wire method." This wire method is especially useful in checking very accurate work, such, for example, as thread gages, and ordinarily it would not be employed in checking parts in connection with ordinary manufacturing practice because thread gages require much less time and are preferable for shop measurements. The three-wire method, however, is frequently used for precision work. Three wires or pins of the same diameter (within very close limits) are placed in contact with the screw thread, as illustrated by the diagram. Two

wires are placed in contact with the thread on one side and a third wire on the opposite side. When the micrometer is in contact with all three wires, this insures measuring perpendicular to the axis of the screw thread.

The rule or formula for determining the measurement M over the wires may be based either upon the pitch diameter or upon the major or outside diameter D. The final result will be the same, assuming that the pitch diameter and the major diameter are the basic dimensions in each case. The formulas which follow do not compensate for the effect of the lead angle but they are sufficiently accurate for checking single-thread screws unless exceptional accuracy is required; these are the formulas ordinarily used.

General Formulas for Any Thread Angle: The general formulas which follow are for determining either the measurement over the wires when the pitch diameter of the screw thread is correct or the pitch diameter equivalent to a given measurement over the wires. These general formulas may be applied to any thread angle. Assume that

M = measurement over the wires when pitch diameter is correct;
E = basic pitch diameter of screw thread;
W = wire diameter;
t = one-half the thread angle in the plane of the axis = 30 degrees for American Standard thread, 27½ degrees for British Standard Whitworth, 14½ degrees for Acme Standard.

To determine the correct measurement M for a given pitch diameter, use the following formula:

$$M = E - \frac{0.5\,P}{\tan t} + W\,(1 + \operatorname{cosec} t)$$

To determine the pitch diameter E equivalent to any measurement M, use the following formula:

$$E = M + \frac{0.5\,P}{\tan t} - W\,(1 + \operatorname{cosec} t)$$

Simplified Formulas for Given Thread Angles: The general formulas just given can, of course, be simplified for any given thread angle. For example, if the thread angle is 60 degrees, then

$$M = E - \frac{0.5\,P}{0.57735} + W\,(1 + 2) = E - 0.86603\,P + 3\,W$$

This formula may be applied to any 60-degree thread, such as the American Standard, a sharp V-thread, or American Standard straight pipe thread.

Formulas Based upon Major Diameter: When the formula is based upon the major or outside diameter, it must take into account not only the thread angle, but the thread depth; consequently, formulas for an American Standard thread, a sharp V-thread, and a pipe thread are all different, because, while the angle is the same, the thread depths vary in each case.

For American Standard thread: $M = D - (1.5155 \times P) + (3 \times W)$.

For a sharp V-thread: $M = D - (1.732 \times P) + (3 \times W)$.

For a straight pipe thread: $M = D - 1.6656\ P + 3\ W$.

In these formulas, D equals the basic outside diameter. The formula for the sharp V-thread has the largest constant of 1.732 because the thread depth equals 0.866 times pitch of thread. The depth of a standard pipe thread equals 0.8 times pitch, thus reducing the constant to 1.6656: the depth of the American or U. S. Standard thread equals 0.6495 times pitch.

Pitch Diameters of Screw Threads: All references here to major and pitch diameters relate to the basic dimensions.

Pitch diameter of American Standard thread = major diameter — (0.649519 × pitch).

Pitch diameter of British Standard Whitworth thread = major diameter — (0.640327 × pitch).

Pitch diameter of Acme Standard thread = major diameter — (0.5 × pitch).

Pitch diameter of 29-degree worm thread = major diameter — (0.6866 × pitch).

Pitch diameter of sharp V-thread = major diameter — (0.866 × pitch).

Thread Micrometer. The pitch diameter or angle diameter of a screw thread may be determined by using a special thread micrometer. This micrometer has a fixed anvil which is V-shaped so as to fit over the thread while the movable point or spindle is cone-shaped at the end so that it will enter the space between two threads. The anvil and the spindle make contact with the sides of the thread, thus enabling the "angle diameter" or pitch diameter to be determined.

Thread Milling. There are two general methods of forming screw threads by milling, which may be designated as the single-cutter and the multiple-cutter methods. Whenever a single cutter is used, the axis of the cutter is inclined in order to locate the cutter in line with the thread groove at the point where the cutting action takes place. The lengthwise traversing movement is applied to the cutter on some machines and to the screw being milled on other machines. The single-cutter process is especially applicable to the milling of large screw threads of coarse pitch

and the heavier classes of work. For fine pitches and short threads, the multiple-cutter method is preferable because it is more rapid. The object of using a multiple cutter instead of a single cutter is to finish a screw thread complete in approximately one revolution of the work. In order to finish the thread complete in one revolution (plus a slight amount of over-travel), it is necessary to use a cutter which is at least one or two threads or pitches wider than the thread to be milled. In using a multiple cutter it is simply fed in to the full thread depth and then either the cutter or screw blank is moved in a lengthwise direction a distance equal to the pitch of the thread. See also Planathreading.

Thread Rolling. The rolling process of forming screw threads may be defined as an impression or displacement method, since the thread grooves are not cut by an edged tool but are formed by means of a die or roll having threads or ridges which are forced into the metal and, by displacing it, produce a thread corresponding to the required shape and pitch. The plain blanks upon which threads are to be rolled are somewhat smaller in diameter than the finished thread, because the rolling process displaces a certain amount of metal which is forced up above the original surface of the blank, thus producing a screw thread which is larger in diameter than the original blank. The increase in diameter is approximately equal to the depth of one thread. No material whatever is removed by the rolling process, the metal from the depression formed by the die simply being forced up on either side. When screw threads are produced by the rolling or displacement method, there are two general processes:

1. By rolling the blank in contact with a revolvable disk or roll, the periphery of which has either a single thread or a multiple thread corresponding in pitch to the thread required. This method is employed when threads are rolled in automatic screw machines.

2. By rolling the blank in contact with flat dies having parallel ridges which are spaced in accordance with the required pitch and which form the screw thread. Machines designed exclusively for rolling screw threads on such parts as machine screws, bolts, wood screws, etc., are equipped with flat dies.

3. By the rotary or circular method. In a type of thread rolling machine employing this method a cylindrical die, rotating on its axis and provided with thread grooves on the outside, is set horizontally within a hollow cylindrical die having threads on the inside. Screw threads that are within the range of the rolling process may be produced more rapidly by this method than in any other way, which accounts for the use of thread-rolling machines in connection with bolt and screw manufacture.

Blank Sizes: According to the practice in different plants where thread rolling is done, there are three general classes of blank sizes, including: (1) Those which are a little larger than the pitch diameter; (2) those which are approximately equal to the pitch diameter; and (3) those which are slightly less than the pitch diameter. The sizes in the first class are intended for screws which are to be rolled as accurately as possible. The blank diameters for screws in this class varying from ¼ to ½ inch usually are from 0.002 to 0.0025 inch larger than the pitch diameter, and for screws varying from ½ to 1 inch or larger, the blank diameters are from 0.0025 to 0.003 inch larger than the pitch diameter. Threads of the second class mentioned, or those rolled from blanks which are equal to the pitch diameter, are sufficiently accurate for many purposes. Blanks of the third class, or those which are slightly less than the pitch diameter, are intended for bolts, screws, etc., which are made to fit rather loosely, a comparatively free fit being desirable in many cases. Blanks for this grade of work, according to common practice, are from 0.002 to 0.003 inch less than the pitch diameters for screw threads varying from ¼ to ½ inch, whereas, for screw thread sizes larger than ½ inch, the blank diameters are frequently from 0.003 to 0.005 inch less than the pitch diameter. The blanks for screw threads smaller than ¼ inch are usually from 0.001 to 0.0015 inch less than the pitch diameter for ordinary grades of work, and about the same amount larger than the pitch diameter for more accurate screw threads.

Thread-Rolling Steel. Soft steel containing from about 0.07 to 0.12 per cent carbon is suitable for thread rolling. The use of "liquor"-finish soft steel wire has been recommended to minimize wear on both the header and the thread rolling dies. If the "liquor"-finished wire cannot be obtained, a good grade of annealed and cleaned wire may be employed.

Wire of the following composition has proved satisfactory for thread rolling. Carbon, 0.08 to 0.12 per cent; manganese, 0.35 to 0.45 per cent; phosphorus, 0.03 to 0.04 per cent; and sulphur, 0.03 to 0.04 per cent. This material has a tensile strength of about 56,000 pounds per square inch. Bright basic wire is one of the best materials obtainable, and is suitable both for heading and cold roll threading. This material is hard enough to permit a slot to be cut after the heading operation by means of a slotting machine.

Tolerances: The wire mills will accept a tolerance specification of plus or minus 0.002 inch on the diameter. It is particularly important that this tolerance be maintained on stock used for long screws of small diameter. On screws of short length the material will flow, and if the wire is over size little trouble

will be experienced, but in the case of screws having a length greater than ten times their diameter, the material will be confined, and "burning" will take place, if the tolerance is greater than that specified. If the wire is slightly under size, the rolled threads will have a ragged appearance due to the fact that the crest is not fully formed. On screws under the No. 10-24 size, a tolerance of plus or minus 0.001 inch should be adhered to in order to insure good results.

Three-Square Files. These files are made in taper, slim, and blunt forms. They are double-cut, mostly bastard, and used quite extensively for filing angular surfaces, and for many other purposes. The three sides are of equal width, the angles between them being 60 degrees.

Three-Wire Method of Thread Measurement. See Thread Measurement, Three-wire Method.

Throat of Die Chaser. The throat of a die chaser is the chamfered portion at the leading end of the chaser provided to enable the die to enter readily upon the work to be threaded and distribute the thread-cutting operation over at least two or three chaser teeth.

Throw, Eccentric. See Eccentric.

Thrust Bearing. The term thrust bearing is usually applied to bearings designed primarily for supporting a shaft against a load acting parallel to the axis, the bearing taking an end thrust. Some thrust bearings have plain sliding surfaces, whereas others are of the anti-friction type and are equipped either with ball or roller bearings. The thrusts having sliding surfaces may be divided into two general classes known as step bearings and collar bearings. Step bearings support a shaft at its end, as for example, when a vertical shaft rests in a step bearing. Such bearings often have a number of disks or washers to increase the number of wearing surfaces. Some step bearings are supplemented by high-pressure lubrication so that the shaft is hydraulically supported. Collar thrust bearings are so named because the shaft has projections or shoulders which engage several bearing surfaces, thus distributing the thrust load over these annular ridges or rings about the shaft.

Thurber Rule. This is a rule employed for finding the board measure of logs, as follows: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply the result by the length of the log in feet. The diameter inside of the bark at the small end is measured usually.

Thury Regulator. The Thury regulator is used in electrical machinery for maintaining constant voltage by field resistance

control. The field rheostat is not actuated directly by the voltage fluctuations, but is operated by a small electric motor, the regulating mechanism being merely brought into play or stopped by the fluctuations of voltage.

Thury System. The Thury system is a high-voltage direct-current transmission system for electric power. As used in Europe it consists of a number of constant-current commutator type generators which are connected in series to develop the desired transmission voltage. Instead of the current varying with the load, as in the constant-potential alternating-current system, the voltage varies with the load, the current remaining constant. At the distributing end of the system, a series of motors similar to the generators must be used, and each one of these motors must drive an alternating- or direct-current generator for the usual constant-potential distribution.

Tie-Bolt. See Bolts.

Tiller or Hand Rope. This is a wire rope consisting of 6 ropes wound into one main rope. Each of the 6 ropes forming the main rope has 6 strands with 7 wires each. This construction produces an exceedingly flexible rope which can be bent over very small sheaves. It is one of the most flexible standard ropes obtainable, but as it is made from very fine wire, it will not stand much surface wear, and, therefore, should not be subjected to heavy loads.

Tilted Turret. The turrets of most turret lathes revolve about a vertical axis, but the turret on some machines is inclined or set at an angle relative to the turret-slide and bed. On one tilted-turret machine, the turret is tilted toward the spindle at an angle of 15 degrees, so that a tool such as a boring-bar or die will be at an angle of 30 degrees from the horizontal when in the rear position. This change in the position of the tools as they are indexed toward the rear enables tools of larger diameter to be used, which is one of the advantages of the tilted turret. Each hole in the turret is continued in a straight line from one side to the other, and there is also a hole through the central turret stud so that it is possible for long bars to extend clear through the turret, when a hollow form of tool is being used. This feature enables long stock to be handled without using a tool having an excessive overhang. Owing to the inclined position of the turret, the strain on the central stud is also reduced, owing to the fact that part of the endwise thrust of the cutting tools is taken directly by the angular surface of the turret-slide. Some large turret lathes are equipped with turrets which are inclined toward the rear of the machine, instead of toward the

spindle, so that long cutter bars, etc., will be at their highest point when passing the front of the machine. Turrets are mounted in this way for providing clearance between the tools and the large pilot wheel or turnstile which is used for operating the turret-slide by hand.

Timbers for Structural Use. The strength of timbers, such as are used for structural purposes, depends chiefly upon the density or weight per cubic foot of the dry wood and also upon the character, size, number and location of defects. According to U. S. Government tests, the allowable bending stresses in the extreme fiber may vary, in pounds per square inch, from 650 for northern white cedar and Englemann spruce, up to 1400 for Douglas fir (No. 1 structural grade) and dense southern yellow pine. The allowable bending stress for white pine and western red cedar is 800; eastern hemlock, red gum, red or white spruce, and silver and soft maple, 900; redwood and Norway pine, 1000; sound southern yellow pine and Douglas fir of No. 2 structural grade, 1100; white or red oak, 1200; and hickory, 1500 pounds per square inch.

Time Limit Device. A device used in connection with overload electric circuit-breakers when it is desired to prevent tripping due to momentary overload or rushes of current at starting. They are also used in relays to delay the opening or closing of a circuit for a predetermined period. The time limiting arrangement may consist of an oil or air dashpot, thermostatic heating arrangement, weighted spring, vibrating reed, charging condenser, etc., for governing the length of time delay after the impulse is received before the circuit breaker or relay is actuated. In the case of the circuit-breaker, if the overload persists beyond the predetermined time limit, the breaker is tripped.

Time Study. That part of "scientific management" which is concerned with the time required for doing certain work is referred to as *time study.* Time studies may be divided into two kinds: Simple time studies, in which the time element only is analyzed, and complete time studies, which include motion studies or an analysis of the various motions required for performing certain work. Complete time studies, therefore, include observation of wasteful methods and inefficiency and their elimination; standardization of conditions and operations; the setting of the tasks to be performed by the workmen; and the determination of the reward to be given for individual efficiency. It naturally also includes the making of estimates on work to be made and the ascertaining of costs in advance. In properly conducted systems of scientific management, time studies are not undertaken with a view to speed up or drive the workmen, but with the idea of

standardizing approved methods by means of which the work should be done, so that the workmen may be able to accomplish more work without greater exertion. See also Methods-Time Measurement.

Tin Amalgam. This is an alloy of tin and mercury, used for silvering mirrors.

Tin and Its Properties. Tin is a soft metal of white color, almost entirely devoid of tenacity. Its specific gravity varies according to the treatment; cast tin has a specific gravity of about 7.29, rolled tin, 7.30, and electrically deposited tin, from 7.14 to 7.18. Tin melts at a temperature of 232 degrees C. (450 degrees F.), and boils at a temperature of about 1600 degrees C. (about 2900 degrees F.). Its specific heat is 0.056, and its coefficient of linear expansion per unit length, per degree F., is 0.000015. Its thermal conductivity is about 15 (silver = 100), and its electrical conductivity, about 13 (silver = 100). If tin is exposed for any length of time to very low temperatures (—40 degrees F., for several hours), it becomes so brittle that it disintegrates into a powder. Tin is used in its pure state in the chemical industries for containers, stills, etc. It is employed for making tin foil, for silvering mirrors, for wrapping food products, and for tinning cooking utensils, because it is proof against acid liquids. The most important uses of tin in the idustries, however, are in the various alloys which it forms with copper, antimony, and lead. Bronze is, perhaps, the most well known of these alloys, it being composed of copper and tin, the copper content being usually from 80 to 90 per cent, while the remainder is tin. The greater part of tin produced is employed in the making of tin alloys. Tin is the only one of the more important metals that is not produced in the United States to any appreciable extent. The Federated Malay States, Bolivia, and the Dutch East Indies produce the bulk of the world's supply of tin.

Tin Foil and Lead Foil. Lead foil consists of lead with a very light tin coating, whereas tin foil is made of practically pure tin. The production of lead foil, in a plant where large quantities of both lead and tin foil are manufactured, is as follows: Cast ingots of lead about 24 inches square and 1 inch thick are passed through the first break-down mill, thus reducing the ingot thickness to about 1/2 inch and increasing the length to about 42 inches. A casing or covering of pure tin, about 1/64 inch thick, is next placed on the top and bottom of the ingot which is then passed through the next break-down mill. Two more passes, or four in all, reduce the ingot to a thickness of about 1/16 inch and increase the length to approximately 40 feet, after which one pass is usually all that is required in the finishing mill. Lead foil,

common foil or "four per cent," as it is sometimes called, contains about 4 per cent tin and 96 per cent lead.

Tin foil, which is made from cast ingots of tin, is produced by the same general process, although tin foil is given eight passes through the finishing mill. Tin foil is usually mounted on wax paper, but pure tin foil is also used alone for packaging food.

Tin Plate. Tin plates are made by coating soft sheet steel with tin to protect the steel from corrosion. They are made in sizes of 10 by 14 inches and multiples of that measure, the most commonly used sizes being 14 by 20 and 20 by 28 inches. The "base weight" of tin is equivalent to the weight of a standard "base box" which contains 112 sheets of 14- by 20-inch size. In the trade, the expressions "charcoal plates" and "coke plates" are retained from the time when high-grade tin plates were made from charcoal iron and the lower grade of tin plates from sheet iron produced with coke as a fuel, or coke iron. At the present time, however, these terms refer only to the quality of the tin coating and the finish. Charcoal plates have the heaviest coating and the highest polish, while coke plates have a light coating of tin. The latter are generally used for can-making. The amount of coating of pure tin per square foot of plate equals 0.023 pound, according to the specifications of one large consumer of this material. See also Terne-plate.

Tire Bolt. A bolt having a countersunk head at one end and a thread for about one and one-half or two times its diameter for a square or hexagon nut at the other end.

Titanium. Titanium is one of the metallic chemical elements, the symbol of which is Ti, and the atomic weight, 48.1. Titanium has a brilliant white fracture and is harder than steel. Its specific gravity varies from 4.5 to 4.9. It melts at a temperature of 1820 degrees C. (3308 degrees F.). Its specific heat is 0.112. Titanium is most commonly found associated with iron in various iron ores.

This metal is used in its commercially pure state and in alloy form (being alloyed with manganese or ferrochromium) for applications requiring a metal with properties of light weight, high strength, and good temperature- and corrosion-resistance. Titanium and its alloys weigh approximately 44 per cent less than stainless or alloy steels, are equal to or greater in yield and ultimate tensile strength than structural alloys in common use, withstand temperatures up to 800 degrees F. and higher temperatures up to 2000 degrees F. for short periods and are resistant to the corrosive effects of salt water and many acids, alkalis and other chemicals. It is available in the form of plates, sheets, strip, forgings, ingots, bars, rods, and wire.

Titanium Steel. Titanium is one of the elements that have been employed with marked success to improve the quality of steel. It has also been very successfully used for cast iron and for some of the non-ferrous metals. The first heat of titanium steel made in America was poured in 1907, and since that time a great deal of investigaion has been conducted and many experiments have been made. These tests have shown that, when ferrotitanium has been added to steel or iron in very small quantities, it has greatly strengthened these metals and improved their qualities in other ways; it is one of the best of the purifying elements that have been used in the manufacture of steel. The special properties of this steel are in its ability to resist abrasive or frictional wear. In a test made on titanium-steel rails, it was found that, under similar conditions, an ordinary Bessemer rail would wear five times as much during an equal period of time. Titanium steel has been used for gears, tires, and castings in general, and has almost invariably shown a reduction of brittleness and an increase of durability. Titanium tool steels are also used, it having been found that if 0.5 per cent of titanium is present in steel, cutting tools are produced which give much greater durability and high-grade quality.

Endurance Tests: The endurance of titanium-treated steel has been demonstrated by tests on a rotary vibrational testing machine. An open-hearth steel that contained 0.25 per cent of carbon, 0.64 per cent of manganese, 0.425 per cent of silicon, 0.04 per cent of phosphorus, and 0.035 per cent of sulphur, withstood 2,660,000 revolutions at a fiber stress of 38,870 pounds. After this same steel had been treated with titanium, it was given 4,052,200 revolutions at the same fiber stress, namely, 38,870 pounds. The stress was then increased to 40,600 pounds, and the piece stood 10,800,700 additional revolutions without a fracture. The fiber stress was again increased to 42,400 pounds and the piece given 1,918,600 more revolutions. The stress was increased a third time to 44,200 pounds and the piece was given an additional 1,006,300 revolutions before it broke. This was a total of 17,777,800 revolutions for the titanium steel, many of which were given it at an increase of fiber stress, as against 2,660,000 revolutions for the untreated steel.

Titration. In analytical chemistry, titration is the process of ascertaining the quantity of any given constituent present in a compound, by observing the quantity of a liquid of known strength (called a standard solution and usually added from a burette) necessary to convert the constituent into another form, the close of the reaction being marked by some definite phenomenon, such as a change of color or the formation of a precipitate. Titration is also called volumetric analysis.

T-Lathe. The T-lathe or facing lathe operates in the same way as an engine lathe, except that the headstock is set at right angles to the bed, and at its midpoint. The functions of the carriage and cross-slide are thus reversed; turning being done by moving the cross-slide across the ways, and facing by moving the carriage along the ways.

Tobin Bronze. Tobin bronze is a special bronze containing from 59 to 63 per cent of copper and from 0.5 to 1.5 per cent of tin, the remainder being zinc, with the exception of small quantities of other ingredients which are added to improve the quality of the metal. On account of the tensile strength of Tobin bronze and its resistance to the corrosive action of sea water, it is extensively used in marine work for such parts as condenser plates, pump piston-rods, valve stems, valve faces, pump plungers, pump linings, motor-boat shafting, condenser tube plates, etc. When used in the form of bolts, rods, and plates, its resistance to wear and oxidation makes it a most useful material for chemical extract works, tanneries, sugar houses, coal mines, etc. The melting point of Tobin bronze is 1600 degrees F. It can be welded electrically or with a high-temperature welding flame. The non-liability of Tobin bronze to produce sparks makes it valuable for powder press plates and powder mill tools. It has a specific gravity of 8.4 and the weight per cubic inch is 0.3036 pound. The ultimate tensile strength varies from 60,000 to 65,000 pounds per square inch, and the compressive strength from 170,000 to 180,000 pounds per square inch. See Naval Brass or Bronze.

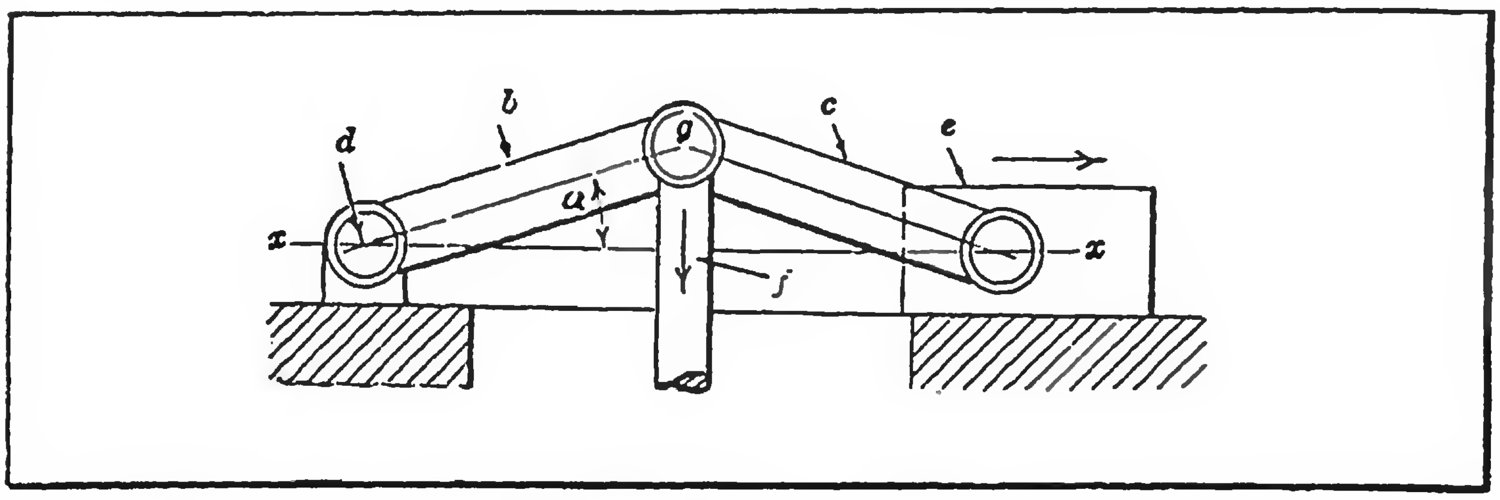
Tocco Hardening Process. Briefly, the Tocco process of hardening steel parts such as automobile crankshafts and camshafts, consists in electrically heating and then quenching with water, individually, each of the surfaces to be hardened. For example, in the case of camshafts, this is accomplished by placing the camshafts between centers mounted on vertical slides, the bottom center in each case being spring-backed to facilitate loading. Each machine is made with one slide for hardening two camshafts simultaneously. After the machines of a group have been loaded with the work-slides in the raised position, windows at the front are closed and the operator starts the machines.

The camshafts while rotating at about 60 revolutions per minute to insure uniform heating, are lowered in successive steps to bring each cam lobe, the helical gear, and the eccentric within the inductor blocks which heat the surfaces. These downward or indexing movements of each work-slide are effected automatically by means of a hydraulic piston and cylinder, and the indexing is controlled by an air-operated plunger at the top of the slide which engages notches on a fixed vertical bar.

As each cam lobe or other surface of the camshafts is brought into the openings in the inductor blocks, 100 kilowatts of electric current at high frequency passes around the surfaces to be hardened and heats them to a temperature of approximately 1500 degrees F. within 4½ seconds. Then cold water is sprayed on the heated surfaces for a period of 7½ seconds through a series of holes in the inductor blocks.

The vertical slide then indexes downward to bring the next cam lobe or other surface of the camshafts into the inductor blocks. The operation of the indexing plunger, the duration of the electric heating, and the period of quenching are all controlled by an automatic timing device. At the end of the operation the work-slide is automatically returned to its loading position by the hydraulic mechanism. Water at about 75 pounds per square inch pressure is used in the hydraulic system.

High speed is a feature of this process, the camshafts for eight-cylinder engines, which have eighteen surfaces to be hardened, being hardened by one man at the rate of one camshaft every 1½ minutes. The camshafts for six-cylinder engines have fourteen surfaces to be hardened, and are handled at the rate of one camshaft every minute. Uniformity of hardening is assured



Toggle Joint Principle

by this process, because once the operating cycle has been established and the power supply adjusted, the human element is eliminated.

Toggle-Drawing Press. Double-action toggle-drawing presses are preferable to drawing presses of the cam type, in all cases where the blanks have been previously cut (even though the stock may be heavy), or where the metal to be cut and drawn simultaneously is of comparatively light gage. The inner plunger of the toggle-drawing press is actuated by the main crankshaft, and the outer blank-holder slide receives its motion from two rock-shafts connected by a system of links with the main shaft. This form of drive imparts a more uniform pressure to the blank than is possible with cam-operated drawing presses.

Toggle Joint. A link mechanism commonly known as a toggle joint is applied to machines of different types, such as drawing and embossing presses, stone crushers, etc., for securing great pressure. The principle of the toggle joint is shown by the accompanying diagram. There are two links, *b* and *c*, which are connected at the center. Link *b* is free to swivel about a fixed pin or bearing at *d*, and link *c* is connected to a sliding member *e*. Rod *f* joins links *b* and *c* at the central connection. When force is applied to rod *f* in a direction at right angles to center-line *xx*, along which the driven member *e* moves, this force is greatly multiplied at *e*, because a movement at the joint *g* produces a relatively slight movement at *e*. As the angle a becomes less, motion at *e* decreases and the force increases until the links are in line. If $R =$ the resistance at *e*; $P =$ the applied power or force; and $a =$ the angle between each link and a line *xx* passing through the axes of the pins, then:

$$2R \sin a = P \cos a.$$

Tolerances. Tolerance is the amount of variation permitted on dimensions or surfaces of machine parts. The tolerance is equal to the difference between the maximum and minimum limits of any specified dimension. For example, if the maximum limit for the diameter of a shaft is 2.000 inches and its minimum limit 1.990 inches, the tolerance for this diameter is 0.010 inch. By determining the maximum and minimum clearances required on operating surfaces, the extent of these tolerances is established. As applied to the fitting of machine parts, the word tolerance means the amount that duplicate parts are allowed to vary in size in connection with manufacturing operations, owing to unavoidable imperfections of workmanship. Tolerance may also be defined as the amount that duplicate parts are permitted to vary in size in order to secure sufficient accuracy without unnecessary refinement. The terms "tolerance" and "allowance" are often used interchangeably, but, according to common usage, *allowance* is a difference in dimensions prescribed in order to secure various classes of fits between different parts.

Unilateral and Bilateral Tolerances: The term "unilateral tolerance" means that the total tolerance, as related to a basic dimension, is in *one* direction only. For example, if the basic dimension were 1 inch and the tolerance were expressed as 1.00 — 0.002, or as 1.00 + 0.002, these would be unilateral tolerances, since the total tolerance in each case is in one direction. On the contrary, if the tolerance were divided, so as to be partly plus and partly minus, it would be classed as "bilateral."

Thus, $1.00 \begin{smallmatrix} +0.001 \\ -0.001 \end{smallmatrix}$ is an example of bilateral tolerance, because the total tolerance of 0.002 is given in two directions — plus and minus. Unilateral tolerances generally are recommended.

When unilateral tolerances are used, one of the three following methods should be used to express them:

(1) Specify limiting dimensions only as

Diameter of hole: 2.250, 2.252
Diameter of shaft: 2.249, 2.247

(2) One limiting size may be specified with its tolerances as

Diameter of hole: 2.250 + 0.002, —0.000
Diameter of shaft: 2.249 + 0.000, —0.002

(3) The nominal size may be specified for both parts, with a notation showing both allowance and tolerance, as

Diameter of hole: 2¼ + 0.002, —0.000
Diameter of shaft: 2¼ — 0.001, —0.003

Bilateral tolerances should be specified as such, usually with plus and minus tolerances of equal amount. Example of the expression of bilateral tolerances follow:

$$2 \pm 0.001 \text{ or } 2 \begin{smallmatrix} +0.001 \\ -0.001 \end{smallmatrix}$$

How to Apply Tolerances: According to practice approved by the Society of Automotive Engineers, tolerances should show the permissible amount of variation in the direction that is less dangerous. When a variation in either direction is equally dangerous, a bilateral tolerance should be given. When a variation in one direction is more dangerous than a variation in another, a unilateral tolerance should be given in the less dangerous direction. One exception to the use of unilateral tolerances on mating surfaces occurs when tapers are involved. In such cases either bilateral or unilateral tolerances may prove advisable, depending upon conditions.

Where tolerances are required on the distances between holes, usually they should be bilateral, as variation in either direction is usually equally dangerous. The variation in the distance between shafts carrying gears, however, should always be unilateral and plus; otherwise the gears might run too tight. A slight increase in the backlash between gears is seldom of much importance.

Basic Dimensions: The minimum hole should be of basic size in all cases where the use of standard tools represents the greatest economy. The maximum shaft should be of basic size in all cases where the use of standard purchased material, without

further machining, represents the greatest economy, even though special tools are required to machine the mating part.

Standardization in Different Countries: National standard fits have been established in the United States, Austria, Germany, Great Britain, Holland, Sweden, and Switzerland. All national standards, except the British, are based exclusively on the unilateral system of tolerances. The British Standard gives both the unilateral and the bilateral systems, recommending the former. The national standards, with the exception of the American, the British, and the Dutch, give both the basic hole and the basic shaft systems. The United States and Great Britain have adopted the basic hole system, Holland the basic shaft system exclusively. The Dutch system is at one extreme, in affording the maximum freedom of choice in the combination of hole and shaft. It specifies limits only, and does not give allowances or tolerances. The other extreme is formed by the type of system adopted by the Austrians, Germans, Swedes, and Swiss, which gives a number of fits completely defined by their allowances and tolerances. The American system lies between these two extremes. The standard reference temperature for gages is 20 degrees C., or 68 degrees F., in all the countries mentioned, except Great Britain, where it is 62 degrees F., or 16 2/3 degrees C.

Tolerances, Gage. See Gage Tolerances.

Ton. One net or short ton = 2000 pounds (commonly used in the United States and Canada); 1 gross or long ton = 2240 pounds (commonly used in England and for certain purposes in the United States).

Ton, Metric. See under Metric System.

Tool Checking Systems. In every tool store-room it is essential to have some systematic method of determining what tools are in use and where they are located in the shop, to prevent loss of tools and to enable any tool to be found readily if necessary. The method which has been adopted almost universally is to use brass checks which are numbered to correspond with numbers given to different workmen. These checks may be placed in the store-room tool cabinet where the tool belongs, or they may be filed on a board in the store-room, so that the number of tools in the possession of any particular workman may readily be determined. There are various modifications of this checking system which are intended either to simplify the system, or to make it a more effective means of accounting for tools and of preventing mistakes or fraudulent practices.

Single Check System: The single check system, as commonly applied to tool-rooms, is so arranged that each workman has a certain number of checks which he receives when first employed.

These checks, as previously mentioned, are stamped with the employe's number, and whenever he obtains a tool from the store-room, a check must be given to the tool-room attendants as a receipt. This check, according to the usual method, is placed on a hook located where the tool belongs in the bin, rack or drawer of the cabinet. When the tool is returned to the tool-room the check is given back to the workman. If the tool should be sent from the tool-room to the grinding department or forge shop, a special tool-room check is either put in its place or a written record is kept; consequently, the location of every tool not in the store-room is shown either by the number of the workman's check or by a tool-room check or a separate record.

Double Check System: When a single check is exchanged for a tool and is placed where the tool belongs in the tool cabinet, it might be impossible for the man in the tool supply room to determine how many tools a workman has in his possession without examining the entire stock of tools, providing there were no separate record. The double check system shows the number of tools received by each workman and for that reason is preferred in some plants. With one system there is a board in the tool store-room which has two check hooks for each employe and near each pair of hooks there is a label giving the name of the employe and the corresponding check number. When a man is engaged by the concern he is given a certain number of round checks, and a corresponding number of square checks are hung on one of the hooks opposite his name on the store-room board. Whenever a workman receives a tool, he gives a round check in exchange for it and this check is placed on the hook adjacent to the man's name and number. At the same time, a square check from the opposite hook is removed and inserted in that part of the tool cabinet from which the tool was taken. When this tool is returned, the square check is replaced on the board and a round check on the other hook is given back to the workman. With this system the number of round checks hanging opposite each name shows how many tools that particular man has in his possession, without searching through the tool cabinet. The square checks, which are also numbered, show who received the tools that are not in the tool racks.

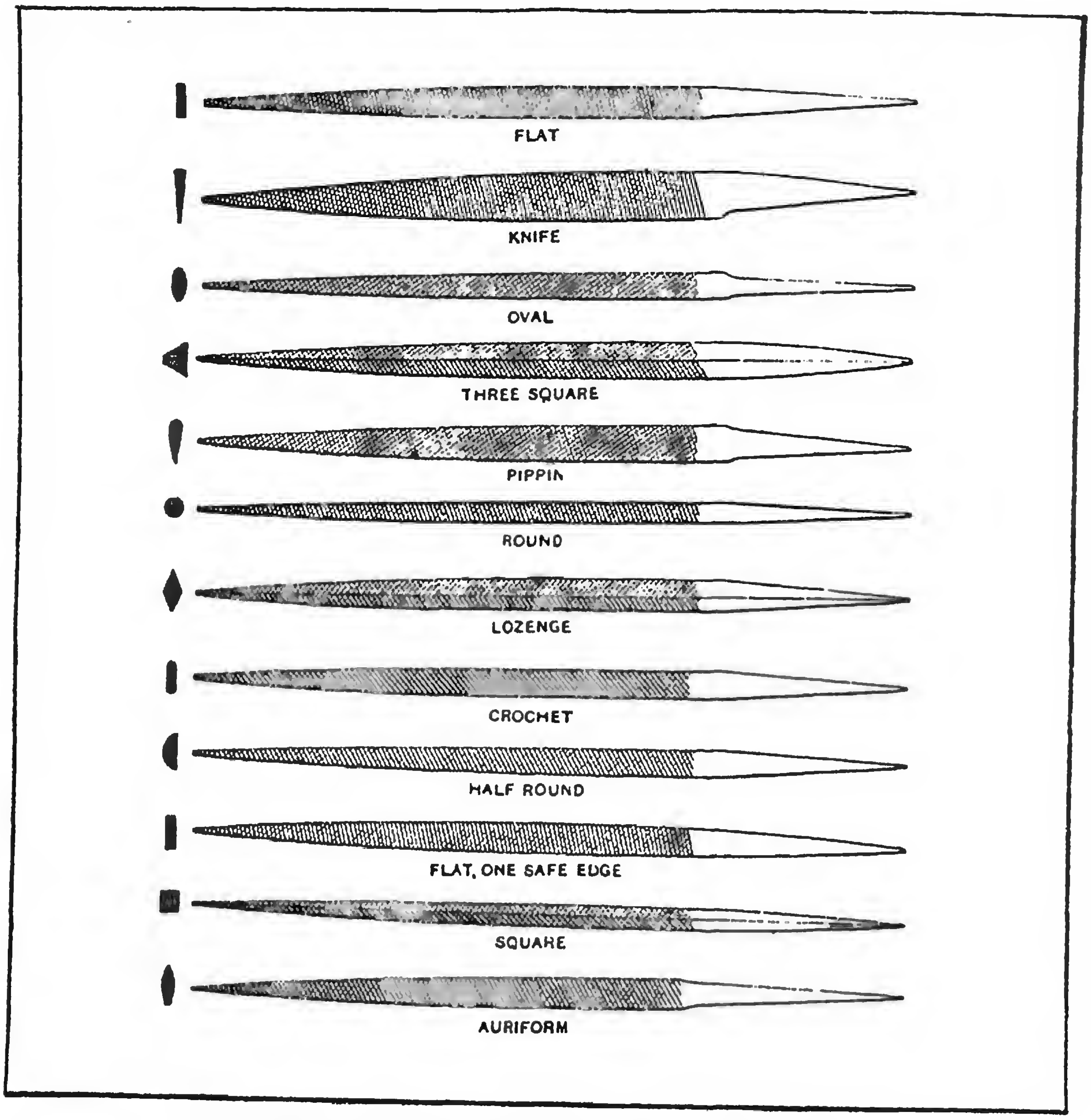
Tool-Grinding Machines. The turning and planing tools used in lathes, planers, etc., are ground in special tool-grinding machines in many shops, instead of by the workmen on an ordinary grinding wheel. These machines are designed to hold and guide the tool mechanically, as it is brought into contact with the grinding wheel. When these tool grinders are used, the tools which have been sharpened by them are kept in a tool- or storage-room, and each workman obtains from this stock of tools as

many as may be required. There are several important advantages connected with the grinding of tools by means of these special machines. In the first place, when the tools are ground in this way, it is not necessary for the workman to stop his machine and go to a grinding wheel; moreover, a machine designed especially for this class of work makes it possible to grind all the tools to standard angles of slope and clearance, which have been found to give the most efficient results. With this system of sharpening and storing the tools, a smaller stock will be required, which is another important advantage.

Tool-Holders. The tools used in lathes, planers, and other turning and planing machines may either be forged to shape from a bar of steel and form a solid one-piece tool or such tools may consist of tool-holders into which relatively small pieces of steel are clamped so as to form the cutting point or end. The practical introduction of tool-holders began in about 1866, when W. Ford Smith, of Manchester, England, in a paper read before the Institution of Mechanical Engineers, described a system of tool-holders for cutting metals. Some of these tool-holders were adapted for round cutters made from ordinary bar steel and others for cutters of a deep V-section having a rounded bottom edge. The use of tool-holders and inserted cutters gradually spread until, at the present time, tools of this type are used very extensively, and for many classes of work they have replaced the solid forged tools. A typical form of tool-holder, such as is used for turning operations, consists of a drop-forged shank or holder in which a small tool-steel cutter is clamped. One of the important advantages of this arrangement is that very much less tool steel is required than when the entire tool is forged from a solid bar of tool steel; consequently, the expense for tool steel is very much less in shops equipped with tool-holders, especially at the present time when costly high-speed steels have so generally replaced carbon steels. The expense of forging and reforging solid tools is also eliminated when tool-holders are used, since the cutters are of uniform section and are simply adjusted outward as the ends are ground away.

Toolmakers' Files. A marked difference in files was found formerly between those of domestic manufacture and imported Swiss files, appropriately called by their makers "files of precision"; but as these files of precision are now successfully produced in the United States, the terms "domestic" and "imported" have largely lost their significance as designating two distinct classes of files. Toolmakers' files ordinarily vary from 2 to 12 inches in length and the cuts are not named but numbered. The first five numbers correspond approximately in fineness (the

number of teeth to the inch) to the domestic files as follows: No. 000, same as "rough"; No. 00, same as "bastard"; No. 0, same as "second-cut"; No. 1, same as "smooth"; No. 2, same as "super-smooth." All toolmakers' file cuts above No. 2 to No. 8 have no equivalent in ordinary files. The exact number of teeth per inch varies in both classes of files and with the different makes of the same class, but not sufficiently to make the differ-



Set of Die-sinkers' and Toolmakers' Files—
Length, 3½ Inches

ence noticeable until the file is used. To avoid mistakes in ordering files of precision, the order should invariably specify toolmakers' files. The toolmakers' file is distinguished by its sharp outline, the teeth extending to the extreme points and edges. In width and thickness, these files are also more slender than common files, and somewhat lighter. The illustration shows various shapes.

Toolmaker's Flat. This term is applied to a precision surface plate which is used in conjunction with precision gage-blocks when an extremely accurate base or plane surface is required. The toolmaker's flats made by the Pratt & Whitney Co. are about 5 inches in diameter and 7/8 inch thick. They are made of special alloy steel, hardened, and given a special stabilizing treatment to insure permanent accuracy. The top and bottom surfaces are lapped flat and parallel within 0.000010 inch.

Toolmaker's Lathe. Lathes of this class are made with a greater degree of precision than ordinary engine lathes, and are more expensive; they are equipped with special attachments which adapt them to the varied line of work connected with toolmaking. Among the features which are common to a toolmaker's lathe may be mentioned the taper attachment, the collet chuck in the spindle, and the relieving attachment for backing off the teeth of milling cutters.

Toolmaker's Microscope. A toolmaker's microscope is designed for general use in checking both linear and angular measurements in connection with screw threads, gages, small jigs, and various classes of precision work. One make consists of a microscope mounted vertically above a compound table having longitudinal and lateral movements controlled by accurate micrometer screws. Parts to be inspected are either held in a special attachment or placed directly upon the table in the field of observation, within which is a "spider-line cross" and angular graduations.

Toolpost Grinding Attachment. See Grinding Attachment, Toolpost.

Tool Steel. Tool steel, as the term is used in the machine-building industry, may be defined in a general way as any steel that is suitable to be used as a cutting tool, or a steel which contains a sufficient amount of carbon so that it will harden if heated above a certain temperature and rapidly cooled. This broad definition includes, under the head of tool steel, both high-speed steels and plain carbon steels. Steel for many of the cheaper grades of tools and implements is made by the open-hearth process but is known as "tool steel."

The crucible process was formerly used for making all the high-grade tool steel used for metal-cutting tools and, consequently, the terms "tool steel" and "crucible steel" are often used interchangeably, but at the present time the electric furnace is used extensively for producing tool steel which should not be classified as crucible steel.

Torch Hardening of Gear Teeth. See Flame Hardening.

Torque and Horsepower. Torque or turning force about an axis of rotation may be expressed in pound-feet or in pound-inches. Torque varies according to the speed and power transmitted. If T = torque in pound-inches, H.P. = number of horsepower, R = revolutions per minute,

$$T = \frac{\text{H.P.} \times 63000}{R}\text{; or H.P.} = \frac{TR}{63000}$$

If L = load or pressure in pounds exerted at any radius and r = radius in inches to point or path where load is applied,

$$L = \frac{\text{H.P.} \times 63000}{R \times r}$$

Example: A spur gear having a pitch radius of 6 inches rotates 500 revolutions per minute and transmits 10 horsepower. Determine the torque in pound-inches; also the tangential load in pounds at the pitch circle.

$$T = \frac{10 \times 63000}{500} = 1260 \text{ pound-inches}$$

$$L = \frac{10 \times 63000}{500 \times 6} = 210 \text{ pounds}$$

A load of 210 pounds applied at a radius of 6 inches equals a torque of $210 \times 6 = 1260$ pound-inches.

Torque in pound-inches can, of course, be converted into pound-feet by dividing by 12. The term pound-feet is used in preference to foot-pounds since the foot-pound is a unit of work and should not be used to indicate torque or turning moment.

Torsional Test. This test is made by gripping a bar at each end; one end is held rigidly and the other is twisted while a weighing device indicates the twisting force required.

Torus. A torus or ring is a circular or ring-shaped body having a circular cross-section. The circular end link often used on a chain, for example, is mathematically known as a *torus*.

Toughness. Toughness is a combined measure of the strength of a metal and its ability to be deformed permanently without rupture. While toughness cannot be measured directly, the impact strength or shock resistance can be taken as an indication of the toughness.

Tower's Experiments. These are a series of experiments that were undertaken to determine the effect of friction in bearings, according to which the following laws were formulated: 1. Temperature and velocity remaining constant, the friction co-

efficient is proportional to the nominal pressure, and the work done against friction is independent of the load, providing this does not exceed from 400 to 600 pounds per square inch. 2. Nominal pressure and velocity remaining constant, the coefficient and, therefore, the work done against friction is inversely proportional to the temperature of the bearing.

Trace. The expression "trace," in a chemical analysis, refers to an amount of an element too small to be determined exactly. It is possible, by taking a large quantity for the analysis and by the very highest refinement in the work, to actually weigh a trace, but in ordinary work it is not done, nor is it usually necessary. In ordinary commercial analysis, it is customary to carry out the percentages of the various ingredients to one-hundredth of one per cent (0.01 per cent), but further than this, except in exceptional cases, it is deemed unnecessary. A substance present in this quantity is very small, and is generally considered as the limit of practical analytical determination, so that less than 0.01 per cent is usually too small to determine, and is called a "trace." A trace of an ingredient is, therefore, an amount which is present in the substance analyzed, but is too small to admit of quantitative determination.

Tracing Cloth. Tracing cloth is largely used for the original drawings of machine parts, etc., in order to make blueprints from the fairly transparent tracing. It is made of finely woven and very smooth cloth, coated with a preparation for the purpose of giving it a fine surface for the use of the pen, and also rendering it transparent. One side is smooth and glossy while the opposite side usually has a dull finish. Drawings may be made on either side. It is easier to erase inked-in lines on the glossy side, but it does not take the ink as well, and the surface should be prepared before inking by rubbing powdered chalk or talcum powder into it with a cloth or chamois skin. It is easier to ink-in a drawing on the dull side, but it is more difficult to make changes.

Tracing Paper. Tracing paper (thin, transparent paper) from which blueprints may be made, is very useful for temporary work, or when there is to be very little handling of the tracing. There are tracing papers, such as bond paper, vellum, or parchment paper, etc., that are strong enough to stand considerable hard usage. Some of the best classes of tracing papers are very tough, transparent, and strong and may, for many purposes, be substituted for tracing cloth.

Traction Sprocket. A traction sprocket, also known as face sprocket, is a sprocket used with a detachable link-belt when the chain makes a reverse bend, so that the open end of the link rides

on the sprocket. The base diameter of such a sprocket must be greater than that in an ordinary link-belt sprocket, the pitch diameter remaining the same. The teeth of traction sprockets generally have a sharp point, to distinguish them from the standard sprockets.

Tractive Force. The approximate tractive force of a locomotive of the single expansion (not compound) type may be determined as follows: Multiply the square of the cylinder diameter in inches by the piston stroke in inches, and multiply the product by 85 per cent of the boiler pressure in pounds per square inch; then divide this total product by the diameter of the driving wheels in inches. If the locomotive is a two-cylinder compound, multiply together the square of the low-pressure cylinder diameter, the piston stroke, the boiler pressure, and a constant of 0.52, assuming that the cylinder ratio is about 2.5 to 1; then divide this total product by twice the diameter of the driving wheels. The *draw-bar pull* of a locomotive is, as the name indicates, the power that a locomotive is capable of exerting at the draw-bar and for pulling the train; hence, the draw-bar pull is somewhat less than the tractive force, as the latter includes the power required to overcome the resistance of the locomotive itself.

Tractrix. The curve known as a *tractrix,* frequently also called the "Schiele" curve or the "anti-friction" curve, has been supposed to give the correct outline for an end-thrust bearing, because the wear in the direction of the axis of the thrust shaft will be uniform at all points when the pivot is given the form determined by this curve. It has been shown, however, that the merits of a pivot bearing shaped in this manner have been greatly over-estimated; and the term "anti-friction," applied to the curve, is a misnomer, since the friction of the bearing designed in accordance with it is greater than that of a flat step or collar of the same diameter.

Trademark. A trademark is an arbitrary sign, word, or symbol used to distinguish one manufacturer's product from that of another, and to impress a particular article on the mind of the public. The value of a trademark consists of an assurance to a manufacturer or merchant of protection in the exclusive use of the name, sign, or symbol, by which his product becomes known. The trademark is a guarantee of the genuineness of the marketed article, and may be said to be, in this respect, the commercial substitute for an autograph. The protective value of the trademark may be compared with the protection afforded by a fundamental patent, as the trademark is used not only in connection

with patented articles but also with commodities not patented nor patentable.

A trademark must not in any way be descriptive of the product nor should it be in the least deceptive. For instance, if a trademark for a soap were claimed on the word "Magnetic," the claim would be rejected on two grounds. First, because soap could not be magnetic, and so the word would be deceptive and misleading, and second, because the term would be descriptive if correctly employed. A proper name, geographical term, or the names of cities, etc., also cannot be used as trademarks. The first letters in the words of a company's name are frequently used with the abbreviation of company. For example, a coined word such as "Seeco" is arbitrary and meaningless, and it would be proper subject matter for a trademark, provided it had not been used previously.

Technical and Non-technical Trademarks: A trademark which complies with all of the rules and regulations, is neither descriptive, geographical, or the mere name of a person, etc., is known as a *technical trademark;* whereas a trademark that does not comply is known as a *non-technical trademark.* The main difference between the two lies in the amount of protection afforded to either under our trademark laws. When a technical trademark is infringed by another party, the infringement may be stopped and judgment be obtained for damages and profits regardless of the intention of the infringer. But where a non-technical trademark is infringed, judgment can only be obtained if there is present an element of unfair competition, that is, a deliberate intent to trade upon the good will of the owner of the trademark.

Registration: Only technical trademarks may be registered in the Patent Office under the 1905 Act. The Act of 1905 particularly provides that registration of a trademark in the Patent Office establishes prima facie evidence that the registrant is the owner. Thus, if you go into court, all you have to prove is that the mark is registered in your name. Then it is up to the defendant to prove that he has a better right to the mark than you have. In the absence of any proof either way, you will be considered the owner of the mark. Registration of a mark in the United States Patent Office establishes Federal Jurisdiction, provided, of course, that both parties have used the trademark in interstate commerce. The use of an unregistered trademark is upheld by the common law, but when registered there is prima facie evidence of ownership.

Train of Mechanism. Any series of gears, links, cams, chain drives, belt drives, etc., used to transmit motion (regard-

less of their order or combination) is known as a train of mechanism. If motion is transmitted entirely through gearing, the combination of gears is called a *gear train*. Trains of gears, pulleys, etc., are common to all classes of mechanisms and may be necessary either for obtaining a required velocity ratio or for transmitting motion when the driving and driven members are so located that a more direct method of transmission is not practicable. Motion is often transmitted through trains of gearing specially arranged so that speed changes may readily be obtained by manipulating suitable controlling levers.

Tram Crane. This type of crane is similar to a traveling crane, except that the bridge is very short and not provided with a trolley, so that the load can be moved only in the direction of the bridge itself, which travels longitudinally on overhead rails.

Transfer Calipers. Calipers provided with an auxiliary arm which can be located so that the calipers may be opened or closed to the original setting, if required. Calipers of this type are generally used for inside measurements, and are employed for measuring recesses where it is necessary to move the caliper points in order to remove the calipers from the place where the measurement is taken.

Transfer Machines. These specialized machine tools are used to perform various machining operations on parts or parts in fixtures as the parts are moved along on an automatic conveyor which is part of the machine tool set-up. In a set-up, the parts can move in a straight line from their entry point to their exit point, or the setup may be constructed in a U-shape so that the parts are expelled near where they start.

Transformer. An electrical transformer, also known as a static transformer, may be defined as a stationary—i.e., not rotary—apparatus for changing alternating currents from a higher to a lower voltage or vice versa and at the same frequency. The possibility of efficiently changing the voltage of alternating current is of great importance, because, usually, the most economical voltages for generating, transmitting, and utilizing electric power differ from each other quite considerably. In fact it is only by virtue of the transformer that long-distance transmission of electric power has been made feasible. It should be noted that some transformers may be used to insulate one circuit from another, although permitting a transfer of electrical energy between them. In such cases there may be no voltage change effected.

Fundamentally, the alternating-current transformer is simple in both construction and operation. If alternating current is

passed through a coil called the primary, an alternating magnetic field is set up. If another coil, called the secondary, is placed close to the primary coil, this primary magnetic field will induce in the secondary coil a voltage directly proportional to the ratio of the number of turns in the secondary to the number of turns in the primary. The resulting secondary current will be inversely proportional to this ratio, and, hence, the product of primary volts times primary amperes is practically equal to the product of secondary volts times secondary amperes. There are losses which are due to the conversion of small amounts of electrical energy into heat but transformer efficiencies are high, usually more than 95 per cent. Usually, a core of laminated electrical steel sheet links both primary and secondary and causes a considerable increase in the magnetic flux linking these two coils.

Two or more single-phase transformers may be combined into an integral unit with a common magnetic circuit to provide polyphase operation. In the case of a three-phase transformer, there are three primary and three secondary windings on a single iron core. A special type of transformer known as an autotransformer has one continuous winding so that primary and secondary are not insulated from each other, but are part of the same circuit. Usually its ratios are close to unity. See Auto-transformer.

Natural air draft transformers are usually small in size and no special provision is made for the dissipation of heat due to internal losses other than to provide some space around the coils for the circulation of air.

Oil-cooled, water-cooled, and *air blast transformers* are usually medium- and large-sized units in which some special arrangement must be made to dissipate the heat resulting from resistance and core losses, so that too great a rise in temperature will not occur.

The transformer is undoubtedly one of the most widely used of electrical devices. In its largest sizes, it functions as a means of stepping up voltages at one end of a power line to the 110- or 220-kilovolt potential which is necessary for long distance transmission, and at the other end to step down the voltage again to a suitable level for primary distribution. It is used on poles for street lighting and secondary distribution to building, lighting and motor circuits. It is used in resistance welding sets to provide the large current flow required in the welding operation. (As designed for this type of application it has a secondary that usually consists of a single turn of heavy copper strap which is necessary to carry the heavy current in the secondary.) It is used with instruments in the measurement of current or voltage in circuits of dangerous line potential so that the instrument

may be placed in a separate electrical circuit at a much safer voltage. It is used in communication equipment for telephony, radio, and television. Here its construction is highly specialized and related more to frequency characteristics than to voltage ratios. (In radio frequency applications, for example, air coils are utilized instead of steel.) It is used to provide the proper operating voltage for ignition in operation of luminous tubes and vapor lamps. It serves the humble function of providing low voltage current for electric door bells. These are but a few of its hundreds of applications.

Transformer Ratio. The ratio of a transformer, unless otherwise specified is the ratio of the number of turns in the high-voltage winding to that in the low-voltage winding; i.e., the "turn ratio." The "voltage ratio" of a transformer is the ratio of the r.m.s. (root mean square) primary terminal voltage to the r.m.s. secondary terminal voltage, under specified conditions of load. The "current ratio" of a current-transformer is the ratio of r.m.s. primary current to r.m.s. secondary current, under specified conditions of load. The "marked ratio" of an instrument transformer is the ratio which the apparatus is designed to give under average conditions of use. When a precise ratio is required, it is necessary to specify the voltage, frequency, load and power factor of the load. The volt-ampere ratio of transformers, which should not be confused with real efficiency, is the ratio of the volt-ampere output to the volt-ampere input of a transformer, at any given power factor.

The circuit voltage has no effect on the ratio of a current transformer. For example, if the transformer is designed for 500 amperes on the primary to 5 on the secondary, this ratio holds true whether it is connected to a 110-volt circuit or a 11,000-volt circuit. The only difference in current transformers designed for high- and low-voltage circuits is in the insulation between primary and secondary windings and between primary and ground. This must be heavy enough to prevent puncture.

Transistor. A transistor is composed of a small block of semiconductor material with three leads attached. Of these leads, at least one is rectifying and one is ohmic. Usually, two are closely spaced and are rectifying, and one is ohmic. Transistors are used in electronic circuits for the purpose of amplifying, detecting or switching.

Transit. The transit is an instrument used in surveying for measuring both horizontal and vertical angles, although for ordinary work the vertical attachment is omitted. This instrument consists of a telescope mounted in standards which are attached

to a horizontal plate called the "limb." Inside of the limb, and concentric with it, is another plate called the "vernier plate." The lower plate, or limb, turns on a vertical spindle or axis which fits into a socket in the tripod head. By means of a clamp and tangent screw, it may be clamped fast in any position, and made to move slowly through a small arc. The circumference of this plate is usually graduated in divisions of either one-half or one-third of a degree, and in the common form of transit these divisions are numbered from some one point on the limb in both directions around to the opposite point which will be 180 degrees. The graduation is generally concealed beneath the plate above it, except at the verniers. This upper plate is the vernier plate, which turns on a spindle fitted into a socket in the lower plate. It is also provided with a clamp by means of which it can be held in any position, and with a tangent screw by which it can be turned through a small arc. The transit generally is provided with a compass, so that the bearing of any given line with the magnetic meridian may be determined, if desired. It also has a spirit level attached to the telescope, so that it may be brought to a horizontal position and made to serve as a level.

Translating Gears. When a lathe is to be used for cutting threads in accordance with both the English and metric systems of measurements, what are known as "translating gears" are sometimes used. These gears have 50 and 127 teeth, respectively, these numbers representing the relation between the English and metric systems of measurement; thus, 1 inch is equivalent to 2.54 centimeters, and $\frac{1 \times 50}{2.54 \times 50} = \frac{50}{127}$. By inserting these gears in the train of gearing connecting the lathe spindle and the lead-screw, it is possible to gear the lathe for cutting a given number of threads per centimeter, the translating gears being used in addition to the same gears that would be employed for cutting a similar number of threads per inch.

Transmission Dynamometers. See Dynamometers.

Transmissions, Hydraulic. See Hydraulic Transmissions.

Transverse Test. A transverse test is made by placing a bar over two supports, loading the bar midway between the supports, and observing the amount of load required to bend or break the test specimen.

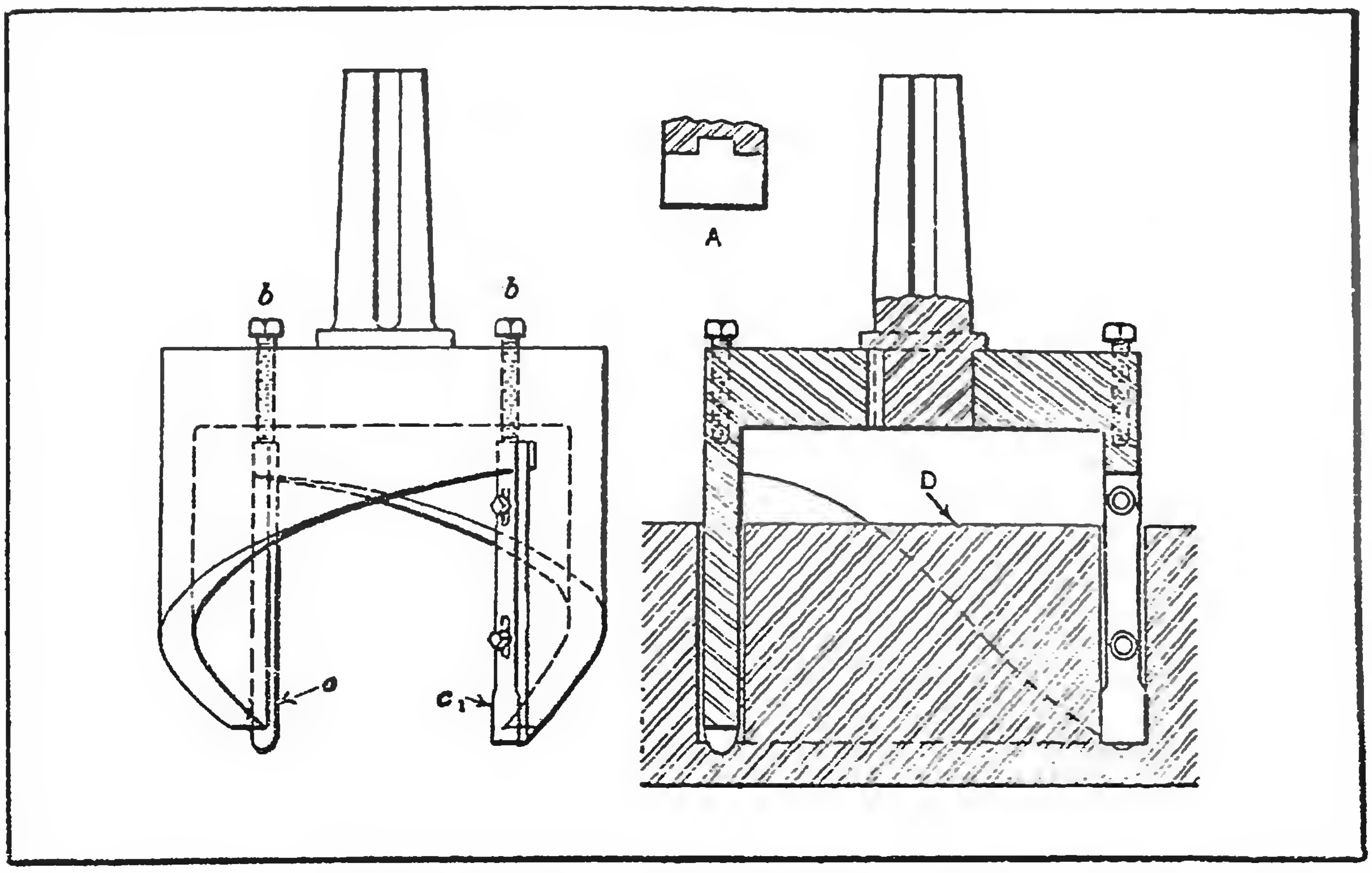
Trapezoid and Trapezium. A plane figure bounded by four straight lines, of which only two are parallel, is called a *trapezoid.* A plane figure bounded by four lines, no two of which are parallel, is called a *trapezium.* These definitions of trapezoid and trapezium, while they are most commonly used in the United States

and sanctioned by several standard dictionaries, are not definitely established as mathematical expressions. There are some dictionaries of the English language in which the definitions of trapezoid and trapezium are interchanged. This is particularly the case in dictionaries published in Great Britain.

Traveling Crane. This is a crane for raising and lowering loads in which there is, in addition to the lifting motion, provision for two horizontal movements at right angles to one another, so that the load can be picked up or deposited at any point within a rectangle formed by the movement of the crane. A traveling crane consists mainly of a bridge or girder spanning the bay of a shop or foundry or a space over a yard, this bridge moving longitudinally on overhead tracks provided at its ends. On this bridge is mounted a trolley or crab which moves in a transverse direction along the bridge. These two movements provide for motion in two directions at right angles to each other.

Trap Rock. This rock when crushed is used as an aggregate for concrete, and as a road-building material. It is a very fine-grained dense igneous rock that is dark in color and is found in California, the Northwestern states, the Atlantic coast states, and Texas.

Trepanning. When a comparatively large hole must be cut "from the solid" a trepanning tool is sometimes used. This tool is so designed that it forms a hole by cutting a narrow groove, the central part or core being taken out as a solid piece. The trepanning tool has two inserted cutters c and c_1 (see illustration) which are mounted in a head of such a form as to provide a strong support and, at the same time, give ample chip room—a matter of importance when taking a cut of this kind. Each tool is located and firmly held by a tongue that engages a groove cut in the holder as indicated by the detail view A. The tools are held in place by tap bolts, which pass through slotted holes. The vertical adjustment of the tools is effected by means of screws b passing down from the top of the holder. This adjustment permits setting the cutters so that they will be in a position relative to each other for working to the best advantage. As indicated by the sectional view to the right, this tool, as it is fed down through the forging, removes a solid block of metal D, thus forming a large hole with the expenditure of comparatively little power, since the tools do not have to remove very broad chips. One of these tools has a round cutting edge and the other one a square edge. With this arrangement, the round tool cuts a central groove, whereas the square tool cuts away the sides, thus forming a channel wide enough to clear the tool-holder. By grinding the tools in this way, the work of cutting is distributed.



Trepanning Tool for Large Holes

Triangles. A triangle is a plane figure bounded by three straight lines. If all the three sides of a triangle are of equal length, it is known as *equilateral*. If two sides are of equal length, it is known as *isosceles*. If one angle is a right, or 90-degree angle, the triangle is a *right* or *right-angled* triangle. If all the angles are less than 90 degrees, the triangle is an *acute* or *acute-angled* triangle. If one of the angles is larger than 90 degrees, the triangle is an *obtuse* or *obtuse-angled* triangle.

Triangles for Drafting. When a T-square is used for drawing horizontal lines, in connection with mechanical drawing, vertical and inclined lines are usually drawn with the aid of triangles. A common form of triangle has one angle of 90 degrees and two angles of 45 degrees, and another common form has one angle of 90 degrees and the other two of 30 and 60 degrees. See Drafting Machines.

Triblet. It is necessary to control the inside diameter of a drawn tube, as well as the outside, otherwise the reduction would all take place from the outside and leave the walls of the tube very thick. In order to properly gage the inside of the tube while it is being drawn through the die, the inside is kept from closing in by the insertion of a steel mandrel or "triblet." This triblet is a rod which is slightly smaller in diameter than the tube over which it is drawn, and must be of a length longer than any tube that will be drawn over it. To the end of the triblet is welded a hardened steel tip, the shape and size of which gage the inside

of the tube. At its opposite end it is secured to the center of a bar that has a sliding action of five or six inches over two bolts in the standard of a bench at the rear.

Triflex. A rubber lining consisting of a layer of hard rubber cushioned between two plies of resilient soft rubber. The three plies are vulcanized together to form an integral lining structure which is bonded to a steel tank with an adhesion above 500 pounds per square inch. For lining steel tanks to meet the severe conditions encountered in cleaning steel with acids. Can also be applied effectively to pipes, valves, fittings, drums, pumps, etc.

Trigonometric Functions. See Functions of Angles.

Trimmer. A trimmer is usually a hand-operated machine and is used in patternmaking and other wood-working shops, for squaring ends, trimming the ends of segments, etc. It is provided with a scale for cutting the miters of all regular polygons.

Trimming Dies. Drop-forgings require trimming after the forging proper is done. The forging comes from the dies with a small amount of fin evenly distributed all around the forging, at the parting line and this fin is removed by the trimming dies. Trimming dies are of two general classes; namely, *hot-trimming* dies and *cold-trimming* dies, according to the condition of the forgings when trimmed.

Steel for Cold-trimming Dies: Dies for trimming cold drop-forgings, according to the practice of the Westinghouse Electric & Mfg. Co., are made from tungsten high-speed steel containing 17 to 19 per cent tungsten, 3 to 4½ per cent chromium, 0.75 to 1.50 per cent vanadium, 0.15 to 0.40 per cent manganese, and 0.60 to 0.75 per cent carbon. These dies are either finished to size before hardening or ground after hardening. The Rockwell C hardness is 60 to 63.

Steel for Hot-trimming Dies: For forgings of small or medium size, a chrome-vanadium steel is used containing 0.80 to 1.10 per cent chromium, 0.15 to 0.20 per cent vanadium, 0.50 to 0.80 per cent manganese, and 0.45 to 0.55 per cent carbon. For large hot forgings, a chrome-nickel steel with from 0.30 to 0.40 per cent carbon is used. These hot trimming dies are finished to size after hardening and the Rockwell C hardness is from 30 to 35.

Trinitro-Toluene. Trinitro-toluene is a commonly used high explosive. As its name indicates, it is a combination of trinitryl and toluol. It is much less dangerous to manufacture or handle than either picric acid or nitro-glycerine, as its fumes are not injurious nor is it sensitive to shock. Heat and moisture have little or no effect upon it, and it refuses to combine with the

metals or their oxides. From toluene is obtained saccharine, which is approximately five hundred times sweeter than sugar. In use, the nitro-toluene is melted and poured into the steel or iron shell, where it solidifies, and is exploded by a time or percussion fuse.

Triple-Action Die. See Drawing Dies.

Tripping Mechanisms. What are known as "tripping" mechanisms are applied to various kinds of machinery to stop the movement either of the entire machine or of some part of it. Automatic tripping devices generally operate in conjunction with a clutch, or they are used to disengage intermeshing gears. The trip may be adjustable and be set beforehand to act after a certain part has moved a given distance, or it may only act when a machine begins to operate under abnormal conditions. The adjustable form of trip, if for a part having a rectilinear motion, may consist simply of a stop which is placed in such a position that it will disengage a clutch after the part under the control of the trip has moved the required distance. If a rotary motion is involved, the same principle may be applied with whatever modification of the mechanism is necessary. If the trip is designed to act automatically only when the machine is operating under adverse conditions, the action may be governed by variations of pressure or resistance to motion; the product on which the machine is working may also cause the trip to act in case the operation is not as it should be.

Trip, Reverse-Current. See Reverse-Current Trip.

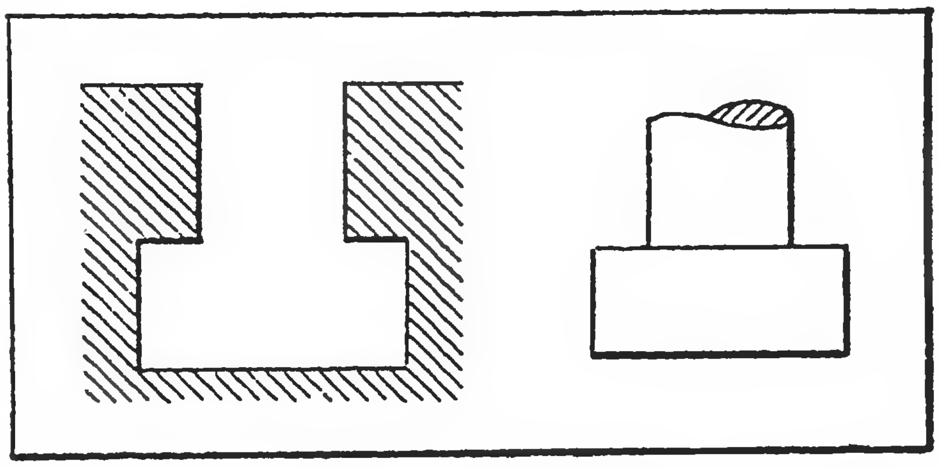
Trodaloy. A copper alloy containing beryllium and chromium, which is much harder and tougher than copper. Particularly useful in withstanding the high pressures and impacts encountered in welding processes. Useful for welding electrodes, switch plates, cams, spring fingers, and mechanical parts requiring high electrical conductivity.

Troostite. That structure or constituent in steel known as troostite is indicative of a tempered steel. When steel is fully hardened it consists of martensite, but as it is heated for tempering, troostite begins to form at about 400 degrees and increases with the temperature until the troostite begins to change into sorbite at a temperature of about 750 degrees.

Troy Weight. The troy weight is used for weighing gold and silver. 1 pound = 12 ounces = 5760 grains; 1 ounce = 20 pennyweights = 480 grains; 1 pennyweight = 24 grains; 1 carat (used in weighing diamonds) = 3.168 grains; 1 grain troy = 1 grain avoirdupois = 1 grain apothecaries' weight.

Truflex. Thermostatic bimetal made in different types for automatically controlling temperature ranges of from —50 degrees F. to 1000 degrees F. Used for automatically controlling the operation of devices either heated or cooled by electricity, oil, or gas, as, for example: electric refrigerators, irons, toasters, gas ranges, water heaters, and domestic oil burners. Available in helical and spiral coils, rings, flat pieces, U-shapes, and in sheets up to 8 inches wide.

T-Slot. T-slots of the cross-sectional shape shown at the left in the illustration are formed in the tables and bedplates of different types of machine tools to receive the T-bolts used to hold either the work or a fixture in position during the machining operation. As there has been a certain amount of variation in T-slot and T-bolt sizes, the American standard has been approved by the American Standards Association, the National Machine Tool Builders' Association, and the American Society of Mechanical Engineers. This standard covers T-bolts and slots for bolt diameters ranging from ¼ inch up to 1½ inches, inclusive, and tables giving the dimensions of American standard T-slots, T-bolts, T-nuts, and T-slot cutters will be found in MACHINERY'S HANDBOOK.



T-slot and T-bolt

T-Slot Cutters. T-slot cutters are a combination of end-mills and side milling cutters. They are generally provided with a solid shank and are used for cutting the T-slots in the tables of machine tools and fixtures.

T-Square. A T-square consists of a thin ruler used as an aid in drawing straight pencil or ink lines, and having secured to it at one end a head, normally set at right angles to it, and adapted to be held against the edge of the drawing board with the left hand. T-squares are made in two forms: Those with a fixed head and those with a swivel or pivoted head which may be secured in any desired angular position by a thumb-nut, in order to draw lines that are not perpendicular to the guiding edge of the drawing board. See Drafting Machines.

Tube Bending. See Pipe Bending.

Tube Classifications. See Pipe and Tube Classifications.

Tube Expanding. Plain boiler tubes or flues are made to fit tightly into the holes in the tube sheet by expanding the ends. This tightening of the tube is done by simply stretching the metal outward against the hole in the tube sheet, by means of a tool called a *tube expander*. There are two general types of these tools—the sectional expander and the roller expander. The sectional type is composed of a number of steel segments which are held together either by a steel band or a ring of rubber; these segments surround a central tapering mandrel which is driven inward in order to force the segments outward, thus stretching the tube. The outer surfaces of the segments are usually so shaped that the tube is not only expanded against the wall of the hole through the tube sheet, but enlarged on both sides of the tube sheet. This beading of the tube makes the latter serve as a brace against either tensional or compressive stresses. When tubes are expanded by means of thees sectional expanders, this is frequently referred to as the *Prosser method.* The roller type of tube expander has a set of three or more rolls which are mounted in a suitable frame or holder. These rolls bear against a central tapering mandrel which is rotated and, at the same time, forced inward, thus causing the rolls to revolve and gradually expand the tube tightly against the hole in the tube plate. This is frequently called the *Dudgeon method.* The rotation of the mandrel may be effected either by hand or by power.

Tubes, Collapsible. See Collapsible Tubes.

Tube-Shaping Process. Steel or non-ferrous tubing can be formed to practically any regular or irregular outline, including straight, tapered, and rounded sections, by the Dewey Process which consists simply in applying two narrow rollers at the front and back of the revolving tubing. These rollers are moved in and out radially relative to the tube axis as they are fed along the tube, thus giving it the required shape. The process is performed in a machine that resembles a long heavy-duty lathe, the work being held in chucks in a headstock and tailstock and the shaping rollers being mounted on a carriage that is fed along the bed and the work.

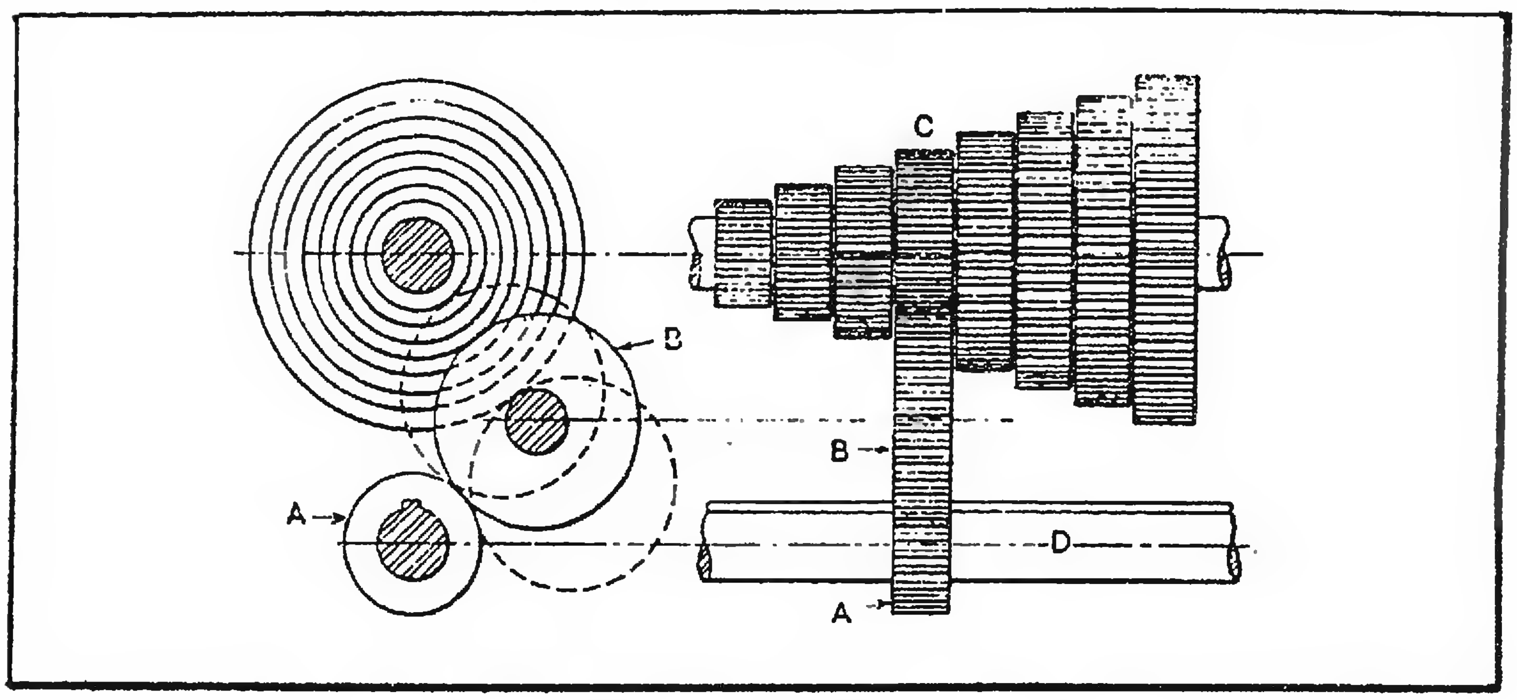
A striking feature of this process is that the wall thickness of the shaped tubing can be increased to obtain greater strength, decreased to reduce the weight of the part, or left the original thickness. Owing to the fact that the tubing expands lengthwise as the rollers change the wall diameter, the tube shaping machine is made with a sliding headstock to allow for this expansion, the tailstock being anchored in a location that is determined by the length of tube being handled.

The process is applicable to both welded and seamless steel tubes and also to tubing made of brass, copper, bronze, aluminum, and Monel metal. The potential applications of tubing shaped by the Dewey Process are practically limitless from the standpoint of both utility and ornamentation. The process is covered by patents issued and pending.

Tube Sheet. The plate or sheet in a steam boiler in which the boiler tubes are held, and in which they are expanded, is called the tube sheet.

Tubing Gages. See Gages for Tubing.

Tubing, Seamless. See Seamless Brass and Copper Tubing; also Seamless Steel Tubing.



Cone of Gears, and "Tumbler" Gear for Obtaining Speed Variations

Tumbler Files. These files are of double oval section but are narrower than crossing files, and the surfaces have smaller radii. They are made in either taper or blunt forms and the teeth are double-cut, bastard, second-cut, or smooth. The tumbler file is not used very generally.

Tumbler Gear and Cone. The type of geared feed-changing mechanism illustrated by the diagram, or some modification of it, is often found on engine lathes for varying the feed necessary for turning, and the speed of the lead-screw for thread cutting. In this particular case, there are eight gears in the form of a cone, which progressively vary in diameter, and, in conjunction with this cone of gears, there is a single gear which may be shifted both radially and axially in order to place it into mesh with any gear of the cone. The exact method of mounting this "tumbler gear" varies. With the arrangement indicated by the diagram, there is a splined shaft *D* upon which pinion *A* is free

to slide. The tumbler gear *B* (which is merely an idler for connecting pinion *A* with whatever gear of the cone may be selected) is held in position by an arm not shown in the illustration. These two gears, *A* and *B*, remain constantly in mesh, and may be shifted to any position along shaft *D*, for engagement with the various gears of cone *C*. In other designs, instead of having a splined shaft *D*, there is a long pinion extending the length of the gear cone with which the idler gear *B* meshes; that is, the construction is similar in principle to the arrangement illustrated, with the exception that gear *A* is a long pinion and the idler gear *B* is shifted along this pinion to the required position. Still another method of applying a tumbler gear is to place it upon a splined shaft (corresponding to shaft *D*) which is adjustably mounted, so that engagement with any gear of the cone can readily be made. Power is transmitted directly between this splined shaft and the gear cone, and the shaft itself is adjusted to the required position for bringing the gears into mesh. Whatever the arrangement for transmitting motion between the shaft and the gear cone, it is the general practice to locate and hold the tumbler gear properly in mesh with the different gears of the cone by means of a series of holes or locating surfaces which are engaged by a locking device attached to the tumbler gear frame or shifting arm, in order to hold it in the proper position. Many lathes are provided with this mechanism.

Tumbling. Tumbling is a process of cleaning, smoothing, brightening, and polishing parts by frictional contact with each other or with some material while the pieces are rotating in tumbling barrels. The tumbling process is also used for a variety of other purposes, such as japanning, painting, and plating metal parts and coloring wood and cork. Tumbling barrels vary in shape, size, and design, but the process in general is the same, although modified according to the type of work and finish desired. Barrel burnishing really comes under the broad definition of tumbling, although the process differs and accomplishes a different result. The usual action of tumbling is to remove or cut away burrs, fins, scale, and flash from parts to obtain a smooth surface or edge. See also Burnishing by Ball Process.

Tumbling Materials. Many materials are used in tumbling, the medium depending upon the work and the finish desired. The action of the mediums ranges from a mere rubbing to an appreciable grinding. A few of the mediums are hard-wood sawdust, gravel, pumice, steel slugs, sand, powdered emery, broken emery wheels, ashes, sandstone, rouge, leather scraps and meal, and tumbling jacks and stars. Water or diluted sulphuric acid is sometimes used for tumbling scaly pieces, or preparatory to some rustproofing operation. Such abrasives as emery, sand, and

gravel are used both wet and dry, the liquid being either oil, water, or a special solution. After the parts are smoothed, they are often polished by rolling in hard maple sawdust, scrap leather, felt, and talc.

When tumbling operations are done simply to dry and clean parts from oil, grease, and water, sawdust is used and the gentle rubbing also brightens the work. Hinges, keys, and small metal parts, such as stampings and screw machine products, and black and lightly scaled parts, are also cleaned by tumbling with sawdust. Flash and burrs can be removed from brass and steel parts, by using steel slugs and sawdust as the tumbling medium, a suitable proportion being two shovelfuls of sawdust to one of slugs. Flash is sometimes removed by tumbling with white sand, gravel, or emery. Sand can be cleaned from brass castings by the use of brass scrap and water. For smoothing and polishing pawls, studs, and miscellaneous metal work, fine sand and ashes can be used.

When parts are to have fairly clean surfaces and a good bright finish is desired, leather scrap or meal free from tannic acid should be the tumbling medium, and enough so used that a cushion will be formed where the work falls back against the shell of the barrel. Steel balls or similar articles can be polished and finished by placing them in a wooden horizontal or tilting barrel for two operations. The first operation should be one of smoothing by tumbling the parts in a Vienna lime mixture, and the next should consist of tumbling the parts in scrap leather, free from tannic acid. These operations give the parts a high luster or polish without cutting away stock. Sometimes in getting parts ready for plating, when it is only necessary to clean off the grease and oil, hot water and alkali is the tumbling medium.

Tungsten. Tungsten possesses the remarkable quality of giving to steel, when alloyed with it, the characteristic of "red hardness," so that a cutting tool made from a tungsten alloy steel can be used at cutting speeds which heat the tool to a temperature at which carbon tool steels would lose their cutting qualities. Most of the tungsten produced is used as an alloying metal for steel. Tungsten is a very heavy metal, its specific gravity in the pure state being 18.8 (weight per cubic inch, 0.68 pound); in its commercial forms, the specific gravity ranges from 19.3 to 20.2, according to the treatment to which it has been subjected. Tungsten may be obtained in the market either in a compact form or in the form of a powder. Tungsten requires such a high temperature for melting that it cannot be melted directly into a mass, but, when first obtained from tungsten-bearing ores, it is always in the form of a metallic powder. This

powder may be worked into solid masses weighing up to two or three pounds. Tungsten does not oxidize readily, and is practically insoluble in the common acids. Its hardness varies from 4.5 to 8 on the Mohs hardness scale (on this scale, razor steel is rated from 5 to 5.5). It is sometimes harder than quartz, which has a hardness of 7, and may be almost as hard as topaz. Its specific heat is 0.034, and its electrical conductivity (silver = 100) is 14.

Tungstenless High-Speed Steel. See Cobaltcrom Steel.

Tungsten Melting Temperature. According to a report on the properties of tungsten, compiled at the Nela Research Laboratory of the General Electric Co., the melting point of tungsten is 3655 degrees C. on the absolute scale, which would be equivalent to about 6125 degrees on the regular Fahrenheit scale The melting point of tungsten is the highest of any substance known, with the possible exception of carbon. The specific gravity of tungsten is 19.3 at room temperature.

Tungsten Steel. This steel is extensively employed for high-speed metal-cutting tools. The property that tungsten imparts to steel is that of hardening in the air after being heated to a high temperature, and that of "red hardness," or the ability to retain its hardness when the tool is heated by the cutting action to a dull red heat. Most high-speed steels contain approximately 18 per cent tungsten, 4 per cent chromium, and 1 per cent vanadium; hence these percentage figures are often combined to designate this high-tungsten steel which has been used much more than any other. See High-speed Steel.

Turbine, Steam. A steam turbine is a prime mover in which steam at high velocity impinges upon the blades of a rotating element, thus transforming the kinetic energy of the steam into mechanical energy. The steam turbine, unlike the reciprocating engine, makes use of the *velocity* of the steam instead of its static pressure. The heat energy of the steam is, through expansion, first changed into kinetic energy, and this in turn is transformed into work by the impulse and reaction effects produced by steam jets discharged through suitable nozzles against vanes upon the periphery of a revolving wheel. In both cases, the work done is due to the heat energy contained in the steam. In the reciprocating engine, the action is intermittent, while in the turbine, it is continuous. The steam turbine is especially adapted to central station work for the following reasons: It has a high speed, with close regulation; it gives high economy under variable loads; it works under conditions of practically adiabatic expansion of steam, the ideal condition sought for in the design of all steam engines; it eliminates cylinder condensation, be-

cause the passages through which the steam flows are always at practically the same temperature; it has no reciprocating parts, with rubbing surfaces to be lubricated; it produces no vibration which calls for expensive foundations; and finally, the floor space required is much less than for a reciprocating engine of the same power.

Turbine, Water. A water turbine may be of vertical or horizontal design. The horizontal turbine may be provided with a casing and be located in the generating room, or it may be of the submerged type and be located in a basin contiguous to the generating room, with the shaft extending through the dividing wall to the generator. The submerged turbine is used only on very low heads, but in some cases it lends itself to an economical and advantageous design of station. The vertical turbine is particularly well adapted for large units. It takes considerably less floor space and, consequently, smaller foundations than the horizontal type. The manufacturer of water turbines is in the best position to make recommendations as to which type of turbine is most desirable for any particular head and capacity. Sometimes the design of the generator is a determining factor, and the solution of this problem is best solved by the manufacturer of generators.

Turbo-Compressors. A turbo-compressor is a multi-stage centrifugal compressor. In principle, it is like the high-lift turbine pump; the air, upon entering the impeller near the center, is thrown outward by the blades, and its kinetic energy, due to the high velocity, is changed into pressure in fixed diffuser channels, and led back toward the center to the inlet of a second impeller, and so on, the pressure increasing with each stage.

Turners for Bar Work. The tools used on flat turret lathes for turning bar stock are commonly known as "turners." These tools are similar in principle to a box-tool, although, according to the general usage of the terms, there is the following distinction between these two classes of tools: A box-tool is usually understood to be a tool having one or more cutters which, while adjustable, are set in a fixed position relative to the work, whereas the tool of a turner is mounted on a pivoted holder, so that it can be withdrawn readily from the working position for clearing a shoulder or a larger diameter on the work.

Turner's Sclerometer. With this form of hardness testing apparatus, a weighted diamond point is drawn, once forward and once backward, over the smooth surface of the material to be tested. The hardness number is the weight in grams required to produce a standard scratch. The scratch selected is one which is just visible to the naked eye as a dark line on a bright re-

flecting surface. It is also the scratch which can just be felt with the edge of a quill when the latter is drawn over the smooth surface at right angles to a series of such scratches produced by regularly increasing weights.

Turntable Lathe. This name is sometimes applied to a turret lathe which has a low circular turret. See Flat Turret Lathe.

Turret Lathe. The characteristic feature of a turret lathe is the turret which is mounted upon a carriage and contains the tools which are successively brought into the working position by indexing or rotating the turret. In many instances, all the tools required can be held in the turret, although it is often necessary to use other tools, held on a cross-slide, for cutting off the finished part, facing a radial surface, knurling, or for some other operation. After a turret lathe is equipped with the tools needed for machining a certain part, it produces the finished work much more rapidly than would be possible by using an ordinary engine lathe, principally because each tool is carefully set for turning or boring to whatever size is required, and the turret makes it possible to quickly place any tool in the working position. Many turret lathes also have systems of stops or gages for controlling the travel of the turret carriage and cross-slide, in order to regulate the depth of a bored hole, the length of a cylindrical part or its diameter; hence, turning machines of this type are much more efficient than ordinary lathes for turning duplicate parts, unless the quantity is small, in which case, the advantage of the turret lathe might be much more than offset by the cost of the special tool equipment and the time required for "setting up" the machine.

Turret Lathe Classification. The name given to turret lathes may either be based upon some prominent constructional feature, or they may be derived from the general nature of the work for which the lathe was primarily designed. All machines which belong to the turret-lathe class are not known as turret lathes, and there is also considerable variation in the names used by manufacturers to designate the different types. Considering first the broad classification of turret lathes, there are the *horizontal* and *vertical* designs; although a very large percentage of the turret lathes in use are of the horizontal design, and those machines which are called *vertical turret lathes* by one manufacturer are classed as *side-head boring mills* by another manufacturer, owing to the fact that they are designed along the lines of a vertical boring mill with the addition of a side head; therefore, the name vertical turret lathe is not one that is applied generally to this type of machine, although such a design may properly be classified as a vertical turret lathe, as it possesses

the same general features as a horizontal machine designed for chuck work.

When a machine is simply referred to as a turret lathe, this is generally understood to be a horizontal machine, and it may be designed either for handling bar stock, chuck work, or both for bar and chuck work, and the turret may or may not have a power feeding movement. A turret lathe that is designed more particularly for turning comparatively small screws, pins, etc., from steel rods or bar stock, is commonly (although not invariably) known as a *screw machine*, or as a *turret screw machine*. According to the practice of some manufacturers, the name screw machine is applied to small turret lathes which have a collet chuck in the spindle and a "wire feed" or a mechanism for feeding a wire rod or bar stock through the spindle. When the machine is intended for either bar or chuck work, or for chuck work exclusively, the name turret lathe is commonly used, and such a machine may or may not have a stock-feeding mechanism which operates in conjunction with the spindle chuck. The foregoing method of distinguishing between the two types, however, is not universal, and there is no general agreement in the use of these names.

Turret lathes of the screw-machine class are sometimes given names which indicate rather definitely the type of machine; for instance, the name *hand screw machine* is often applied to turret screw machines in order to distinguish between the hand-operated type and the automatic type, or the term "hand screw machine" may indicate a design not equipped with an automatic feeding mechanism for the turret slide. The name *wire-feed screw machine* is used by one prominent manufacturer to indicate a design having a mechanism for automatically feeding the stock through the spindle, whereas a machine not having this stock-feeding mechanism is designated as a *plain screw machine.*

Turret lathes are further classified according to the form of the turret. The ordinary turret of the design found on most turret lathes is either hexagonal or round, the former being far more common. The *flat turret lathe* has a turret which is practically a low circular table upon which the tools are clamped, and the name indicates this low, flat design. Lathes of the flat-turret class are sometimes referred to as *turntable lathes.* There is also the *tilted turret lathe,* the turret of which is in an angular position. The *hollow-hexagon turret lathe* is still another machine which derives its name from the form of the turret, although some manufacturers of such lathes do not refer to them as the hollow-hexagon type.

The name in some instances indicates the arrangement of the turret slide. In many cases, the turret only has a longitudinal

feeding movement in the direction of the bed; when there is a cross-slide between the turret and the main slide, the name *set-over turret lathe* is used by some manufacturers, but not very generally. The design of the headstock is another feature which is sometimes considered when classifying a turret lathe. Thus there is the *plain-head type* (without back-gears), and the *geared friction-head type* which has back-gears and friction clutches for engaging either the direct cone-pulley drive or the back-gearing. A great many turret lathes are provided with the geared-friction head. Many modern designs are also equipped with geared head-stocks and either a single driving pulley or a direct-connected motor drive, instead of a cone-pulley.

The *full-swing side-carriage turret lathe* is a design having a toolpost carriage mounted on the side of the bed, so that it will pass the chuck and enable the turret carriage to be moved up close to the chuck, thus reducing the overhang of the tools to a minimum. A turret lathe that is designed especially for work held in a chuck is often known as a *chucking lathe, chucking machine* or as a *turret chucking lathe.* When a turret lathe has such features as an attachment for chasing threads, and a cross-slide for the turret, it is sometimes known as a *universal turret lathe,* because of the increased range of work for which it is adapted. What is known as a *forming lathe,* or a *forming turret lathe,* is similar to an ordinary design, but usually has a carriage between the turret and the headstock that is arranged for carrying wide-forming tools; in some cases, there is a vertical slide at the rear, so that the forming tool may be fed in a vertical plane. Some forming and chucking lathes have a cross-slide for the turret and the latter carries the forming tools.

Turret lathes which are intended principally for brass work are often referred to as *monitor lathes,* the name "monitor" in this connection indicating a revolving turret. This name is not applied to the same design of turret lathe by different manufacturers, although, in general, it indicates a comparatively small turret which, in many cases, is provided with a thread-chasing attachment of the Fox lathe type and is designed principally for turning, boring, and threading parts made of brass. Some lathes which are listed as the monitor type have a stock-feeding mechanism, whereas others do not have this feature. The turret may or may not have power feed, and some monitor lathes have a cross-feed for the turret, whereas others only have the longitudinal feeding movement.

In England, turret lathes are often called *capstan lathes.* The terms "capstan" and "turret," however, are often used interchangeably, although many firms observe a sharp distinction in their application, in that they apply the name "capstan" only to

those machines which have a slide moving in a saddle that is bolted down to the bed, whereas the name "turret" is used when the turret-slide is mounted directly on the bed. The effective difference between the two designs is that the working stroke of the first one is limited by the movement of the turret-slide in the saddle, whereas, with the second arrangement, the longitudinal feeding movement of the turret is limited by the length of the bed.

Turret Lathe Development. The invention of a turret for readily and accurately presenting different tools in successive order, seems to have been the work of more than one man. The invention of the vertical turret has often been credited to Henry D. Stone. The turret principle, however, was not originated by Stone as it had been utilized previously by several others, including F. W. Howe and E. K. Root. The first commercial turret lathe, however, seems to have been built by Robbins & Lawrence of Windsor, Vt., in 1854. One of the earliest turret lathes, if not the earliest, was built in 1845 by Stephen Fitch at Middlefield, Conn. The turret of this machine revolved about a horizontal axis and had eight tool positions. A machine built by E. K. Root at the Colt Armory about 1855 and known as a chucking lathe had a horizontal turret. Another early design by Mr. Root had a vertical turret and a stop-screw for the slide but no automatic tripping device. The movements of the turret of the slide were controlled by a lever at the front of the bed opposite the headstock.

Turret Lathe Sizes. There are two general methods of designating the sizes of turret lathes. If the machine is intended primarily for operating on bar stock which is fed through the spindle, the size of the machine, as listed by manufacturers, indicates approximately, at least, the maximum diameter of stock that will pass through the spindle, and the maximum length that can be turned. For instance, a 2- by 24-inch turret lathe has a maximum capacity for parts 2 inches in diameter and 24 inches long. In some cases, however, the nominal size of the machine is somewhat less than the actual capacity; thus, a turret lathe listed as a 2-inch size may, in reality, be capable of handling bar stock up to 2¼ inches in diameter. The size of a turret lathe intended more especially for chucking operations indicates the maximum diameter that the machine will swing over the ways of the bed; that is, a 24-inch chucking machine is one that will swing parts up to about 24 inches in diameter.

Turret Lathe Slides. Turret-slides for turret lathes may be divided into three general classes: The plain turret-slide, with a longitudinal feeding movement only and a turret that is re-

volved automatically by the backward movement of the slide; the set-over turret-slide, which has a cross motion that is utilized either for recessing or for radial facing with a single-point tool; and the universal turret-slide, which has longitudinal and cross movements similar to the set-over type, but which has, in addition, an intermediate plate between the cross-slide and the longitudinal slide that may be swiveled to allow the turning or boring of tapering surfaces. The cross-slide is below the swiveling member, so that parts may be faced off square with the spindle when the swiveling slide is set for taper work.

Turret Lathe Stops. Practically all turret lathes have some system of stops for regulating the movements of the slides and their tools. Some of the older designs were equipped with a single adjustable stop for all positions of the turret, so that the lengths and positions of the different tools had to be such that all the tools would be properly located when the turret-slide was against the single stop. In order to locate each tool independently, modern turret lathes have multiple stops so arranged that, as each tool is indexed to the working position, there is a separate stop which regulates the point at which the forward movement of that particular tool is discontinued. There are several types of these adjustable multiple stops. Some turret lathes have a revolving cylinder which carries a group of adjustable rods, and in other cases there is a bracket on the bed of the machine containing a number of rods capable of adjustment to the various lengths. Still another arrangement comprises a group of bars in the bed of the machine; each bar is adjustable and has a suitable notch in which a plunger may enter in order to arrest the movement of the turret-slide. On some turret lathes, there is an arrangement which provides for the use of supplementary stops, so that several shoulder distances may be obtained for a single position of the turret.

Tuyere or Twyer. The nozzle through which the blast of air enters a forge or a blast furnace is known either as tuyere or twyer. In blast furnaces the air passes into the "blast-main" or "horseshoe-main" (a circular pipe nearly surrounding the hearth on the outside), and thence through the twyers into the furnace.

Twin-Roller Chain. This is a power transmission chain of the roller type which has, in addition to the links connecting the rollers at the ends, a connecting link in the center, the roller being divided into two parts. In an ordinary roller chain, if the roller is too long, the stud upon which it is mounted is liable to bend. In the twin-roller chain, the stud is supported, and more power can be transmitted with a chain of the same pitch.

Twin-Wheel Grinding. Many parts having two or more diameters must be ground. These diameters are sometimes equal, but usually vary. Frequently the logical method of grinding parts with two diameters is to use two wheels spaced according to the location of the surfaces. This combining of cuts has resulted in large increases in production in some plants. The general arrangement of a twin-wheel machine is the same as for ordinary wide-wheel grinding.

Twist Drill. The term "twist drill" is applied to the common type of metal-cutting drill which has two grooves or flutes that are approximately helical in form, giving the drill a twisted appearance. These helical grooves, because of their inclination, give the two cutting edges rake or keenness and bring the chips to the surface as the drill revolves. See Drills.

Twisted Spur Gears. When helical gearing is used to connect parallel shafts, the term "twisted spur gear" is sometimes used, because the gearing in this case serves the same general purpose as ordinary straight-tooth spur gearing. This relates to the use of single-helical and not the double-helical or herringbone gearing. Twisted spur gears are used to connect parallel shafts in order to secure a smoother action than can be obtained with ordinary spur gears. See also Helical Gears.

Type Metal. Antimony gives to metals the property of expansion on solidification, and hence, is used in type metal for casting type for the printing trades to insure completely filling the molds. Type metals are generally made with from 5 to 25 per cent of antimony, and with lead, tin and sometimes a small percentage of copper as the other alloying metals. The compositions of a number of type metal alloys are as follows (figures given are percentages): Lead, 77.5; tin, 6.5; antimony, 16. Lead, 70; tin, 10; antimony, 18; copper, 2. Lead, 63.2; tin, 12; antimony, 24; copper, 0.8. Lead, 60.5; tin, 14.5; antimony, 24-25; copper, 0.75. Lead, 60; tin, 35; antimony, 5. Lead, 55.5; tin, 40; antimony, 4.5.

A high grade of type metal is composed of lead, 50 per cent; tin, 25 per cent; and antimony, 25 per cent.

Type Metal Bearings. Type metal, used for casting type for the printing trades, is sometimes used for light high-speed machine bearings which are not likely to become heated. For bearings, it is used in the form of a lining like babbitt metal. Type metal is a comparatively cheap alloy, because it contains a large percentage of lead and, when cheapness is an important consideration, there is a tendency to use this lining metal instead of the more expensive babbitt alloys containing copper and tin.

Type metal bearings should not be used, however, when heavy loads have to be supported by the shaft.

Types and Typing. Irregular bosses or ends in a drop-forging die that cannot be finished on the die-sinking machine, and that are particularly difficult to chip out, scrape, and riffle to a finish are often formed by typing. A "type" is a punch or small block of steel the end of which is shaped exactly like that part of the forging that is difficult to cut in the die. Types are hardened and drawn to a purple temper. The part of the die that is to be typed is milled and chipped out to as near the outline and depth as is considered safe. The face of the type is then rubbed lightly with Prussian blue, placed in the impression, and, with a piece of copper or brass on its top, the type is struck hard into the impression with a hammer. This operation leaves the high places with a blue facing. These high places are next chipped away, care being taken not to go too deep, and the process is repeated. If properly done, the typed part of the impression will gradually assume the shape of the type and, by striking in the type a number of times, the impressions will take on the smooth finish of the type and be ready for riffling.

U

U-Bolt. This is a bolt bent to U-form. Both ends of the U are threaded, and such bolts are often used for clamping round parts.

Ultimate Analysis. In chemistry, this is a quantitative analysis in which the percentages of all elements contained in the substance are determined.

Ultrasonic Machining. This method of cutting and engraving hard materials such as glass, precious stones, and carbides uses a transducer (vibratory unit) to obtain the necessary mechanical vibrations needed. (A transducer is any device which converts an input energy into another form of energy. In this case electrical energy is converted into mechanical.)

A tool of the required size and shape is made of brass or other soft material and is attached to the transducer. The tool is lowered until it just barely touches the work, and current is applied. At the same time, a slurry of water and fine abrasive, usually boron carbide, is pumped over the work. The tool does not actually touch the work, but the vibrations literally hammer the particles of abrasive into the surface and chip off tiny fragments. Some wear does take place in the tool, but it is very slight and, as it is equally distributed, it does not change the shape. The method is quite commonly applied to cutting designs in the stones of signet rings, but it is also applied to cutting intricately shaped holes in carbide or hardened steel.

Underload Trip. An underload trip is one that is arranged to trip a circuit breaker when the current flowing through the circuit falls below a certain predetermined amount, the tripping being accomplished by releasing the armature of the magnetic circuit, which, either due to the force of gravity or the energy stored in a spring, forces the armature against the latch, thus releasing it.

Unified Screw Threads. Unified screw threads have been agreed upon by the standards organizations of the United States, the United Kingdom and Canada to provide screw thread interchangeability among these three nations. These Unified threads

are now the basic American standard for fastening types of screw threads. In relation to previous American practice, Unified threads have substantially the same thread form and are mechanically interchangeable with the former American National threads of the same diameter and pitch. The principal differences between the two systems lie in: (1) the application of allowances; (2) the variation of tolerances with size; (3) difference in amount of pitch diameter tolerance on external and internal threads; and (4) differences in thread designation.

In the Unified system an allowance is provided on both Classes 1A and 2A external threads whereas in the American National system only the Class 1 external thread has an allowance. Also, in the Unified system the pitch diameter tolerance of an internal thread is 30 per cent greater than that of the external thread, whereas they are equal in the American National system.

Advantages of Unified Threads: The Unified standard is designed to correct certain production difficulties resulting from the former standard. Often, under the old system, the tolerances of the product were practically absorbed by the combined tool and gage tolerances, leaving little for a working tolerance in manufacture. Somewhat greater tolerances are now provided for nut threads. As contrasted with the old "classes of fit" 1, 2, and 3, for each of which the pitch diameter tolerance on the external and internal threads were equal, the Classes 1B, 2B, and 3B (internal) threads in the new standard have, respectively, a 30 per cent larger pitch diameter tolerance than the 1A, 2A, and 3A (external) threads. Relatively more tolerance is provided for fine threads than for coarse threads of the same pitch. In cases where previous tolerances were more liberal than is required in manufacture, they were reduced.

Uniflow Steam Engines. The uniflow type of steam engine is designed to eliminate one of the greatest losses in reciprocating steam engines, namely, initial condensation. With the uniflow engine, the steam enters the cylinder at the end, after passing through steam-jacketed heads. After expansion has taken place, this steam is exhausted through ports located around the center of the cylinder. The steam flows in but one direction, instead of being returned and exhausting at the end of the cylinder where it enters, as with the ordinary type of reciprocating engine; hence, the name "uniflow." It is claimed that initial condensation is almost entirely eliminated in the uniflow engine, where the ends are kept hot and the center or exhaust belt cooler. The uniflow engine was not designed originally for non-condensing service, but a design known as the "universal uniflow" is adapted to either condensing or non-condensing operations, economical results being obtained under both conditions.

Unilateral Tolerances. See under Tolerances.

Union. The usual trade term for a coupling used to connect pipes. It commonly consists of three pieces which are, first, the thread end fitted with exterior and interior threads; second, the bottom end fitted with interior threads and a small exterior shoulder; and third, the ring which has an inside flange at one end while the other end has an inside thread like that on the exterior of the thread end. Most unions have a gasket which is placed between the thread and bottom ends which are drawn together by the ring. Unions are very extensively used, because they permit of connections with little disturbance of the pipe positions. They are generally classified under two headings, nut unions and flange unions. Nut unions are ordinarily used for 2-inch sizes and smaller, and flange unions for sizes larger than 2 inches. Nut unions are made of malleable iron, brass and malleable iron and all brass. The all malleable-iron union is the standard malleable union of the trade and requires a gasket. The brass and malleable-iron union (known as the "Kewanee") requires no gasket and is non-corrosive. The pipe or "thread end" having an external thread upon which the nut or ring screws is made of brass, and the other pipe end (called the bottom) and the nut or ring, are made of malleable iron. When the union is tightened, the harder iron makes a joint in the softer brass. All-brass unions have a circular or conical seat and no gaskets are required. Flange unions are made of cast iron or malleable iron in three weights, standard, extra heavy and hydraulic. A *lip union* is a special form of union characterized by the lip that prevents the gasket from being squeezed into the pipe and obstructing the flow.

"Unionmelt" Welding Process. This electric welding process has been found particularly advantageous in shipbuilding or similar work, because it enables high-quality welds to be made at comparatively fast speeds by operators who have had relatively little training in welding. As the process is completely automatic, the quality of the weld is not dependent upon the human element. Heat is generated by the passage of electric current from an electrode to the plates being joined. The heated end of the electrode is kept completely covered by a highly resistant granulated material or welding composition known by the trade name "Unionmelt." The entire welding action takes place beneath this granulated material without any visible arc and without sparks, spatter, smoke, or flash; hence, the welders need no protective helmet or goggles. Welding voltage, electric current, speed of operation, and rod feed are all automatically regulated by means of electrical controls to suit a given welding job.

Uni-Polar Machine. Incorrect name for Acyclic Machine, which see.

United States Standard Screw Thread. William Sellers of Philadelphia, in a paper read before the Franklin Institute in 1864, originally proposed the screw thread system that later became known as the U. S. Standard system for screw threads. A report was made to the United States Navy in May, 1868, in which the Sellers system was recommended as a standard for the Navy Department, which accounts for the name of U. S. Standard. The American Standard Screw Thread system is a further development of the United States Standard. The thread form which is known as the American (National) form is the same as the United States Standard form. See American Standard Screw Thread System.

United States Standard Sheet Metal Gage. A gage system originally intended for iron and steel sheets or plates, but replaced for steel sheets by the Manufacturers' Standard Gage. For sheet metal gage tables see MACHINERY'S HANDBOOK.

United States Steel Wire Gage. See Steel Wire Gage.

Unit Plant. A term used in the appraisal of manufacturing plants to designate a unit portion of the equipment of the plant.

Unit Pole. In the science of electricity and magnetism, a unit pole is a pole of such strength that, if placed a centimeter away in the air from a like pole, it will repel it with a force of one dyne; or a unit pole is a pole of such strength that, when placed in a magnetic field of one gauss, it is acted upon by a force of one dyne.

A unit *north pole* is a pole from which 4π flux lines emerge into the air.

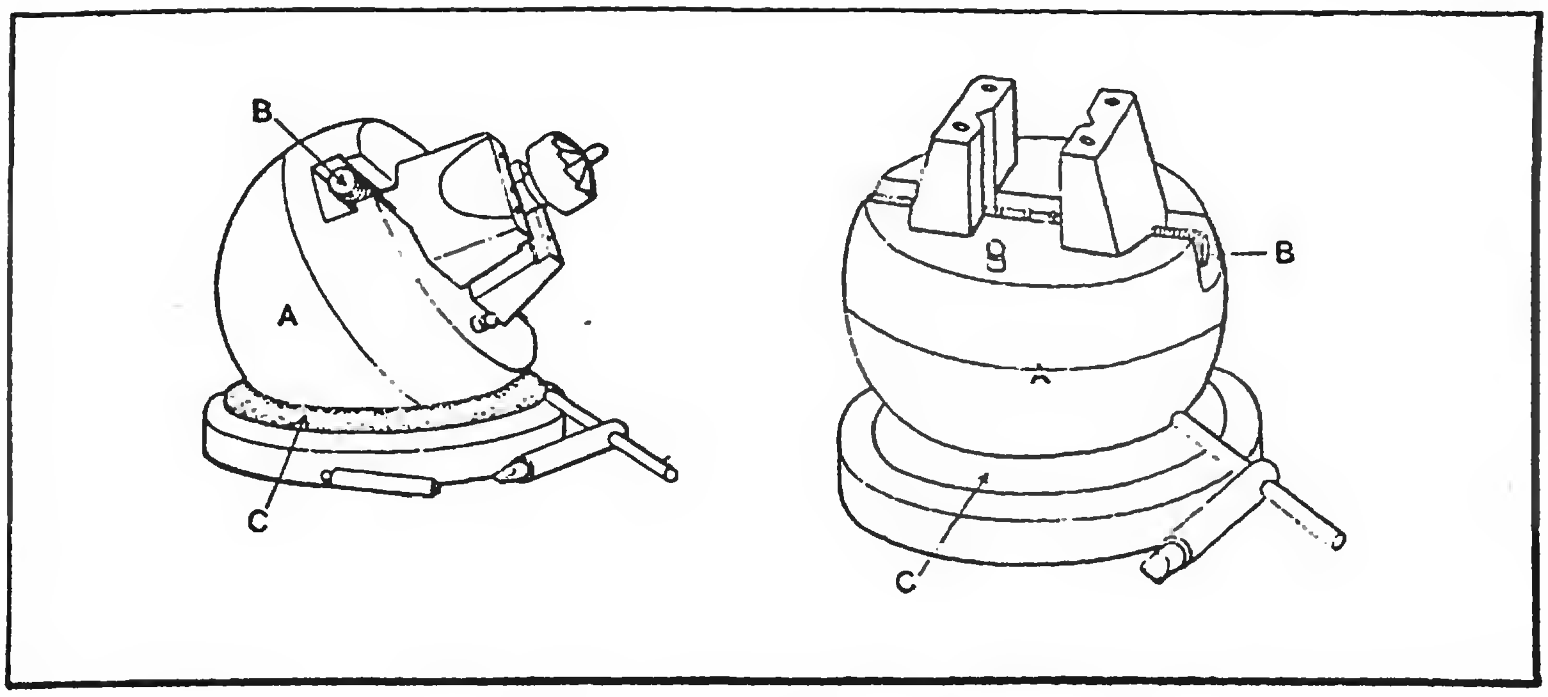
Unit System of Machine Construction. The principle of the "unit system" of construction is simply that of dividing a machine into groups of closely related mechanisms, and constructing them with independent frames or boxes in which the shafts, studs, clutches, gears, etc., are assembled. These units of mechanisms are assembled on the main frame to form the complete machine. The natural divisions of the engine lathe, for example, are the headstock, tailstock, carriage, apron, feed-box, change-gear box, etc. These mounted on the bed, require only the lead-screw, feed-rod, and legs to complete the lathe. This system, which has been applied extensively in machine tool design, has several marked advantages: It is the logical development of the interchangeable system of manufacture which has so greatly re-

duced the cost and improved the quality of manufactured products. The units are made independently in departments suited to the character of the work, by men who, specializing on each particular unit, become experts. The units, being interchangeable, can be replaced by the user when necessary, with a minimum of trouble; they can be removed and returned to the factory for repairs at small expense for freight and handling. The units can be tested independently, and, if defects develop, they are corrected without seriously blocking the output of finished machines. If a complete machine is tested and found faulty, it is held until a minor defect, perhaps, is found and repaired. The same defect found in a separate unit would have been corrected before reaching the assembly floor and thus no delay at this stage would have occurred. An important advantage to the machine tool builder is the ease with which units can be incorporated in various designs. The builder, say, of milling machines, can use the same feed-box in several sizes and styles, and is thus able to produce a variety of designs at a minimum cost for jigs and fixtures, all in harmony with the general design.

Unit Tooling. By "unit tooling" is meant the locating of an entire series of tools used for machining a part, in permanent relation to each other. This is accomplished, in the case of a turret lathe, by providing a special arm or multiple tool-holder, which is fastened to the turret. It is evident that the employment of a unit tooling arrangement is a production expedient only when quantities of work of a standard nature are handled. The expense of making such a tool-holder would not be warranted for special classes of work on which no repetition orders are likely to be received.

Univalent. Univalent, also known as monovalent, is a term used in chemistry to designate that an atom of an element (like hydrogen) combines with but one atom of another element.

Universal Ball Vise. For small fine work, such as die-sinking, stamp cutting, and mold making, the universal ball vise is in general use. The body *A*, see illustration, is of spherical form and rests in a ring-shaped base *C* having enough frictional resistance to prevent the body from turning under normal working conditions. The jaws are operated by a right- and left-hand screw *B* controlled by a socket wrench. The jaws are also drilled at the top to receive pins, so that work can be held between the pins directly on top of the jaws. The illustration at the left shows the vise arranged to hold a small milling cutter while the toolmaker is finishing it. For many purposes connected with fine toolroom work, a vise of this kind is useful.



Vise which May be Adjusted to Different Angular Positions

Universal Chucks. The universal or concentric type of chuck is extensively used on engine lathes because the simultaneous movement of the chuck jaws makes it possible to quickly grip circular parts so that they are located true or concentric with the lathe spindle. The jaws of a universal chuck all move together and keep the same distance from the center, and they can be adjusted by turning any one of the screws, whereas with the independent type the chuck wrench must be applied to each jaw screw. The *combination chuck* may be changed to operate either as an independent or universal type. The advantage of the universal chuck is that round and other parts of a uniform shape are located in a central position for turning without any adjustment. The independent type is, however, preferable in some respects as it is adapted for holding odd-shaped pieces because each jaw can be set to any required position.

Universal Die-Sinker. See under Die-sinking.

Universal Joint. The universal joint is a form of coupling for connecting two shafts which are so placed that their center lines intersect, but are not in the same straight line. Shafts so located may be connected by a universal joint which will transmit the motion from one to the other. This joint has also been called a "Cardan joint" or a "Hooke's coupling" after the Italian who first described it and the Englishman who first applied it. Its form varies according to the particular application.

Universal Milling Machine. The universal milling machine was invented by Joseph R. Brown in 1861. This should not be confused with the so-called universal miller designed by Frederick W. Howe in 1852. The latter machine had certain universal adjustments, such as a chuck that could be indexed and inclined in

two planes and a vertically adjustable cutter-slide. The machine designed by Mr. Brown was a universal type according to present-day usage of the term and it was designed for such operations as helical milling, gear cutting, and various jobs requiring either indexing or a combined rotary and axial motion. The first universal machine made by the firm then known as J. R. Brown & Sharpe was sold to the Providence Tool Co. in 1862, and was used in making special tools for the manufacture of United States Government rifles. For information about the mechanical features of universal machines see Milling Machines, Universal Type.

Universal Motor. A universal motor is a series-wound or a compensated series-wound motor which may be operated either on direct current or single-phase alternating current at approximately the same speed and output. These conditions must be met when the direct-current and the alternating-current voltages are approximately the same and the frequency of the alternating current is not greater than 60 cycles per second.

Such motors, in the fractional horsepower sizes, find a wide variety of applications, such as portable electric drills, floor polishes, sewing machines, food mixers, and other machines where close speed regulation is not required.

Universal Radial Drilling Machine. A radial drilling machine of the *plain type* can only be used for drilling holes at right angles to the base. The universal radial drilling machine is adapted to the drilling of holes at various angles with the base. The head and spindle of a "full universal" machine can be set at an angle with the radial arm, and the arm itself can also be rotated about its own horizontal center or axis, so that the drilling spindle can be placed in almost any position.

Universal Shapers. When a shaper has a work-table which can be swiveled about an axis that is parallel to the line of motion, and has an auxiliary tilting side, which has angular adjustment with reference to the axis about which the main table swivels, it is sometimes known as a *universal* shaper. A shaper designed in this way is especially adapted for tool and die work, owing to the universal adjustment. The range of such a machine may be still further increased by means of extra attachments.

Universal Turret Lathe. When a turret lathe has such features as an attachment for chasing threads, and a cross-slide for the turret, it is sometimes known as a *universal turret lathe*, because of the increased range of work for which it is adapted.

Unloader. In air compressors, an unloader is a pressure regulator which closes the inlet pipe of an air compressor and connects the two ends of the air cylinder, when the receiver pressure reaches the maximum point desired.

Upright Drilling Machine. See Drilling Machines.

Upset. To bunch up or enlarge the end of a round rod or blank by hot or cold forging. End pressure is applied in upsetting machines which makes the metal expand sideways and fill the die cavity to the desired shape. The making of bolt heads and nail heads are two examples of upsetting.

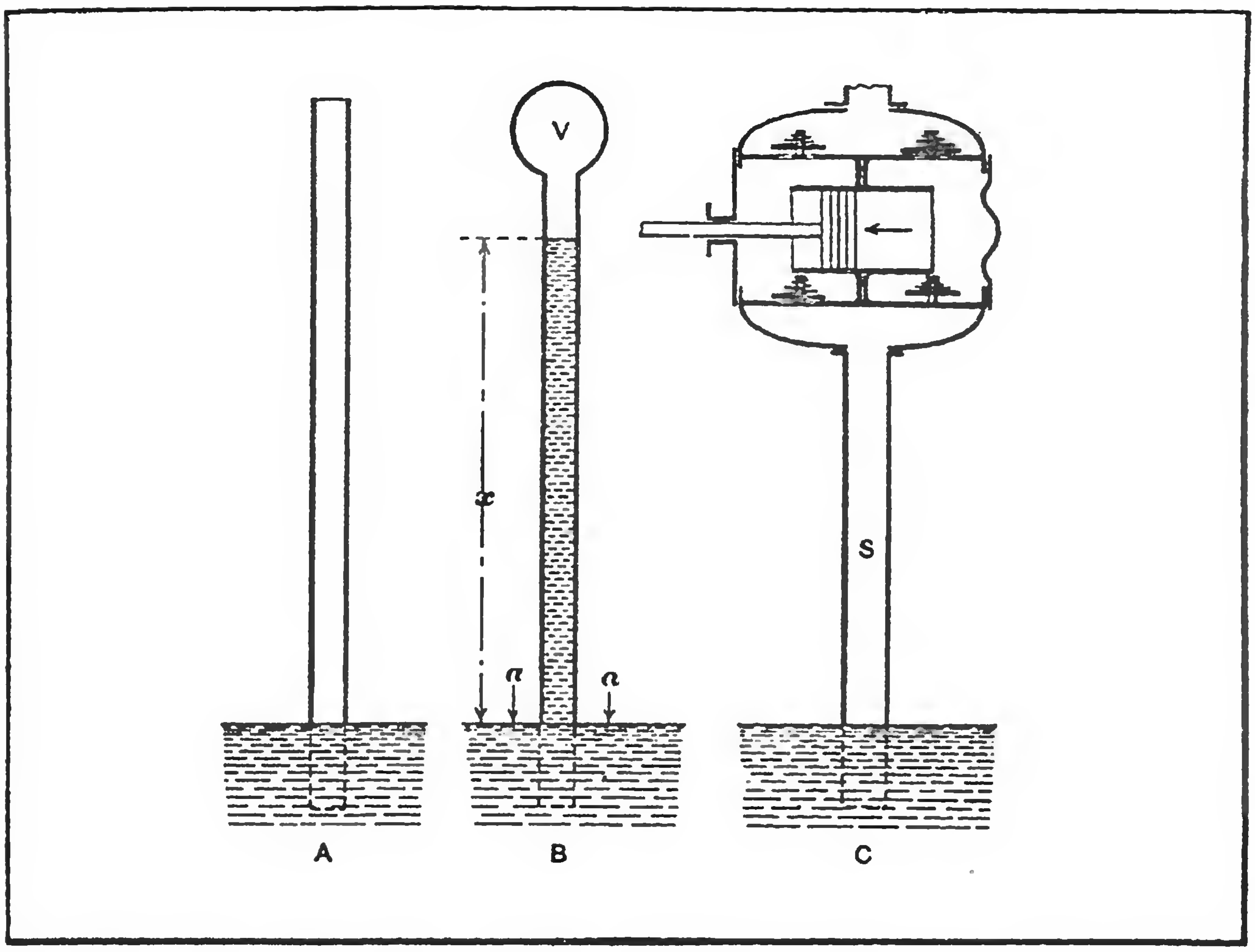
Uranium. Uranium is a white malleable metal which is fairly hard, although softer than steel. Its specific gravity is 18.7, and its specific heat, 0.0276. It melts at a temperature of 2400 degrees C. (4350 degrees F.). It tarnishes very slowly in the air. Uranium is chemically related to chromium, molybdenum, and tungsten. It is claimed that uranium in high-speed steels increases the cutting efficiency and durability to a marked degree.

V

Vacuum. The term "vacuum," as applied in practical engineering, means a partial or more or less imperfect vacuum, the degree of which varies somewhat for different industrial applications and also depends upon the type and condition of the exhausting apparatus. The degree of vacuum is indicated in inches. The reading or number of inches of vacuum at a given time should be related to the atmospheric pressure at that time as indicated by a barometer. To illustrate, assume that the upper end of a mercury column is connected with an enclosed space or vessel from which most of the air or other gas has been removed by an air or vacuum pump. If the height of this mercury column, due to the partial vacuum in the vessel, is 29½ inches when the barometer is, say, 30 inches, this indicates that the pump has created a vacuum that is within ½ inch of a perfect vacuum. In creating a partial vacuum, some form of pump is very generally used. The object may be to lift water from some lower level up to the pump cylinder by utilizing what is commonly referred to as "suction." Many pumps are also designed for exhausting air from an enclosed vessel. In this case, the object may be to lower the boiling point of a liquid within the vessel as in refining sugar and in connection with other industries. Whether a vacuum is utilized in pumping liquids or in exhausting gases, the basic operating principle is the same in each case.

Operation of Pump: The diagrams illustrate the principle involved. If one end of a vertical pipe is submerged in water as indicated at *A*, there will be the same water level inside and outside of the pipe. If the top of the pipe, however, were closed and sealed tightly and the air partially exhausted, the water would rise in the pipe to some height x, the height depending upon the amount of air withdrawn from space V above the water. This vertical movement of the water in the pipe is due to the fact that the atmospheric pressure a on the surface of the water is no longer counteracted by an equal pressure inside the pipe; consequently, the water is forced upward.

The application of this principle to a pump is indicated by diagram *C*. The vertical pipe is connected to a pump cylinder and when the piston is moved in the direction shown by the arrow, whatever air is in the right-hand side of the cylinder at the beginning of the stroke expands and fills the constantly increasing volume caused by the movement of the piston, thus forming a



Diagrams Illustrating Principle of the Vacuum as applied in the Operation of Pumps

partial vacuum. The result is that air is withdrawn from pipe *S* through the suction valves and is forced out past the discharge valve on the return stroke of the piston. If the pump also has suction and discharge valves connecting with the other side of the piston (as shown by the diagram), the return stroke causes a similar movement of the air and water. By repeated movements of the piston, the air is almost entirely removed from pipe *S*, and with each reduction in the amount of air, the pressure is also reduced; consequently, the water is forced by the atmospheric pressure up the pipe and into the cylinder, provided the vertical distance from the water level at the source of supply to the pump cylinder is not excessive. Each time the piston makes a stroke, this water is forced out through the discharge valves and pipe, because the suction valves prevent it from flowing back to the source of supply. When the piston completes a discharge stroke and starts to return, the discharge valves on that side close and prevent a backward flow of water from the discharge pipe into the cylinder.

Vacuum Chucks. For holding pieces made of various magnetic and non-magnetic materials on grinding and milling machines, shapers, planers, lathes, etc., vacuum chucks are used in essentially the same manner as magnetic chucks are employed

for holding pieces made of iron or steel. The upper surface of a vacuum chuck consists of a flat plate perforated with small holes leading to an inside chamber which is coupled up to an exhaust tank. The high vacuum in this tank is maintained by means of a vacuum pump. Each chuck is supplied with a control valve, and as a result, the vacuum chuck is controlled by manipulating a valve in the same way as the magnetic chuck is operated by an electric switch.

Vacuum in Condenser. The vacuum attainable in a condenser is dependent on the temperature of the circulating water available. The average temperature of the water for a priod of four or six weeks during the hot season might be taken as the governing temperature for determining the vacuum to be maintained; then, with colder water, the vacuum will improve. For preliminary considerations, the highest vacuum that may be expected ranges from about 27 inches for a circulating water temperature of 95 degrees F. to 29 inches for a water temperature of 60 degrees F. A condensing turbine will have a steam consumption of about one-half that of a non-condensing turbine, and the power consumption of the condenser auxiliaries will be approximately 5 per cent of the steam supplied to the condensing turbines. The initial cost of the condensing equipment is more than offset by the cost of the additional boilers required for the larger steam production to supply non-condensing turbines.

Vacuum Pump. See Air or Vacuum Pump.

Vacuum Pump, Hydraulic. See Hydraulic Vacuum Pump.

Vacuum Separator. This is a device used for removing oil from the water of condensation in a steam plant, so that the water may be returned to the boilers.

Valence. The valence of a chemical element may be defined as the number of electrons which an atom of that element may gain or lose. The number of electrons which a non-metallic atom may gain is called the negative valence of that element, while the number of electrons which a metallic atom may lose is called the positive valence of that element. When elements combine to form stable inorganic compounds, the sum of the negative and positive valences of the respective components must be equal.

Valence is also used to designate the number of unit charges carried by an ion in solution.

Valve. Valves are used in regulating the flow of liquids or gases which pass through them, and are either controlled by hand or operated by suitable application of power. Valves which are incorporated in the design of engines or other forms of mechanism, such as locomotive slide valves, pump valves, etc., repre-

sent forms designed for a specific purpose as compared with the types used in water pipes, steam pipes, etc. Of the many types of valves in use, hand-operated valves which control the supply of steam or water in pipes are the most common. One of two forms is generally used for these purposes, viz., either the globe or gate valve. In the control of steam, the globe valve in some form is common, while in pipe lines for water or other liquid, the gate valve is extensively used.

Valve, Balanced. In order to assist in the operation of valves that are under heavy pressure, provision is made in certain types of valves called "balanced valves," to equalize the pressure on each side of the valve and thus make the operation easier. Automatic valves also are designed to work on a similar principle, the valve being operated by any change in pressure of the liquid or gas passing through it. A valve of the automatic type is often used for automatically closing a pipe line when an abnormal flow of steam occurs at any portion of the line. Valves of this kind may be placed between each boiler in a battery and the steam header. In the event that a steam main should burst or a cylinder head fly off, or if an injury should occur to the steam line beyond the valve, all the valves of the different boilers in the battery would close immediately and prevent the steam from escaping into the building and doing further damage. In the case of an accident to a single boiler in a battery, such as a burst tube, the valve on that particular boiler would instantly close and prevent all the other boilers connected to the header from emptying their steam through the opening in the injured boiler.

Valve Bronze. This is an alloy composed mainly of copper, tin, and zinc, containing, according to the U. S. Navy specifications, approximately 87 per cent of copper, 7 per cent of tin, 5 per cent of zinc, with a maximum of 0.06 per cent of iron and 1 per cent of lead.

Valve, By-Pass. See By-pass Valves.

Valve Diagrams. In designing a slide valve for a steam engine and the mechanism that operates the valve, it is desirable to be able to determine readily the position of the valve relative to the steam ports, for any given position of the crank or piston. What are known as "valve diagrams" are commonly used for this purpose. These diagrams not only show graphically the relative positions of the valve and crank, but also make it possible to design a valve with reference to a predetermined form of indicator card. Valve diagrams also indicate the effects of changes in the design of the valve on the steam distribution. In connection with steam engine work, certain problems or quantities re-

lating to the point of cut-off, lead, etc., are assumed, and the remaining ones are required and may be determined by means of the valve diagrams. For instance, a designer might be given the point of cut-off, point of release, the lead, and the maximum port opening, the problem being to determine the valve travel, the outside and inside lap, and the angle of advance. By means of a suitable diagram, the valve travel, lap, etc., corresponding to these specified quantities may be readily determined. There are several different forms of valve diagrams, the Zeuner and the Bilgram diagrams being commonly used.

Valve, Gate. See Gate Valves.

Valve Grinding. When the joint between a valve and its seat is formed by a metal-to-metal contact, grinding is commonly resorted to, in order to secure a joint that will not leak when subjected to the pressure of a gas or fluid. The grinding is done by applying some kind of an abrasive between the surfaces of the valve and seat, and the valve is turned in first one direction and then the other, so that any slight imperfection or lack of fit between the valve and its seat will be corrected by the action of the abrasive. When a great many valves have to be ground, they are often turned, while grinding, by machines designed especially for this work. Such machines are often arranged so that several valves may be ground simultaneously. The spindles do not revolve continuously in one direction, but reverse, say, every 1¼ revolution and a cam raises and lowers the spindles at intervals of, say, 20 revolutions, to allow the abrasive or grinding compound to enter the valve-seats.

Valve-Setting Machine. In connection with locomotive valve setting, it is necessary repeatedly to place the main driving wheels at the dead-center positions. There are three general methods of securing the necessary motion of the driving wheels for setting valves. The old method was to move the entire locomotive along the track by means of pinch-bars; obviously, this was a slow laborious method. An improved method is to turn only the main driving wheels, which are simply connected with the cross-heads by the main rods (the side-rods being disconnected), and are mounted on rollers which are rotated either by a hand-ratchet lever or by an air motor. There are two rollers under each wheel, and a supporting frame for the rollers, so that the rollers and driving wheels may be readily rotated. This device is sometimes known as a "valve-setting machine."

Valve Setting, Steam Engine. The adjustment of the valve-operating mechanism on steam engines, for obtaining the correct movement of the valve relative to the piston, so that the steam will be admitted to and exhausted from the cylinder at the right

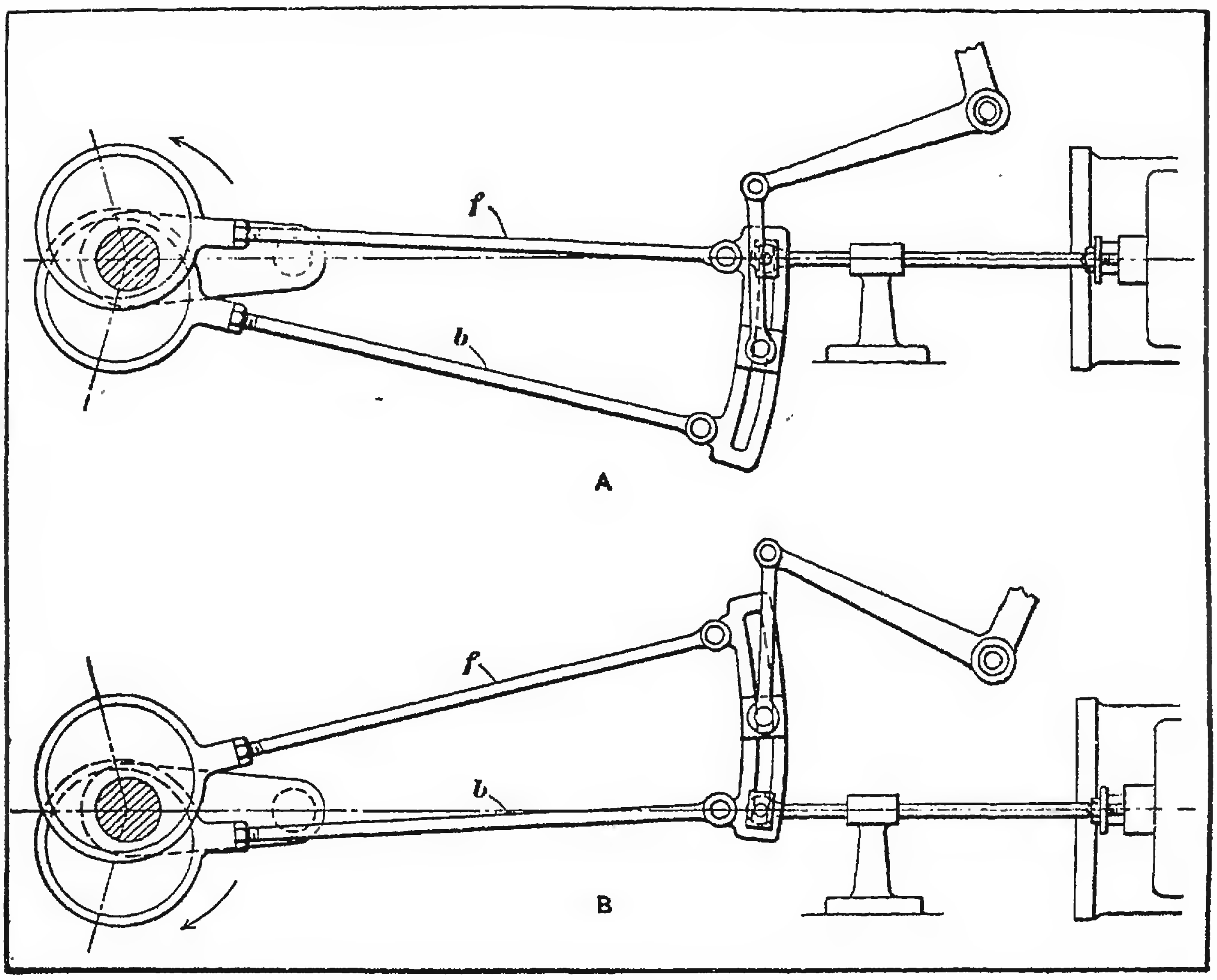


Fig. 1. Reversing Valve-gear set for Forward and Backward Motions

time, is known as *valve setting.* The exact method of setting steam engine valves depends upon the type of engine and design of the valve-operating mechanism. The following information relates chiefly to the fundamental principles involved. In general, the setting of a simple slide valve operated by an eccentric involves two operations: First, the rods which impart motion from the eccentric to the valve should be adjusted so that the valve movement will be equal each way from the central position over the steam ports; second, the eccentric should be so located with reference to the main engine crankpin that the valve opens and closes the ports at the correct time with reference to the movement of the piston.

Direct and Indirect Valve Motions: When the eccentric of a steam engine is so connected with the valve that the center of the eccentric and the valve both move in the same general direction, the motion is said to be *direct.* On the other hand, when there is an intervening rocker arm which reverses the movement and causes the valve to move backward, while the center of the eccentric is moving forward, the motion is said to be *indirect.* The diagrams, Fig. 1, illustrate a direct motion equipped with a link and two eccentrics for reversing the direction of rotation.

Equalizing the Valve Travel: After the steam-chest cover is removed, in order to expose the valve and its seat, begin either by turning the engine or the eccentric one or more revolutions around its shaft, and observe the movement of the valve with relation to the steam ports. (When the engine is large and difficult to turn, it is often much easier and more convenient to simply loosen the eccentric and rotate it about the crankshaft, thus securing the same effect, as far as the movement of the valve is concerned.) When the valve has traveled as far as possible in one direction, measure the distance x (diagram A, Fig. 2), between the edge of the valve and the edge of the port. After taking this measurement, continue turning either the engine crankshaft and the attached eccentric, or the eccentric alone, thus causing the valve to be moved in the opposite direction. When it has reached the opposite end of its travel, as at B, measure the distance y between the other edge of the valve and the edge of the port. Assume that the port opening x was about equal to the port width, and the valve traveled beyond the other port, as indicated by the distance y. In this case, then, the position of the valve on its seat will have to be changed an amount equal to one-half the difference between the distances x and y, in order to make these dimensions equal and equalize the valve travel.

The way in which the position of the valve is changed, in order to equalize its travel, will depend upon the arrangement of the valve-operating mechanism. Ordinarily, the length of the eccentric rod or valve-stem can be varied, or it may be possible to adjust the valve axially along the valve stem, by means of nuts on either side. When the valve movement has been equalized so that the valve travels an equal distance each way from its central position, the first step in setting the valve is completed. The next one is to locate the eccentric in the proper position so that the valve will operate at the right time.

Position of the Eccentric: Before setting the eccentric in relation to the crank, it is first necessary to know in which direction the engine is to run, assuming that it is not reversible. The terms "running over" and "running under" are ordinarily used to indicate the direction in which an engine rotates. When the crank rises at the beginning of the forward stroke and the top of the flywheel turns away from the cylinder, the engine is said to be running over. Inversely, when the crank falls at the beginning of the forward stroke and the top of the flywheel turns toward the cylinder, the engine is running under. Stationary engines ordinarily are designed to run over, whereas locomotives must, of necessity, run under when moving forward. When engines are running over, the vertical thrust of the cross-head

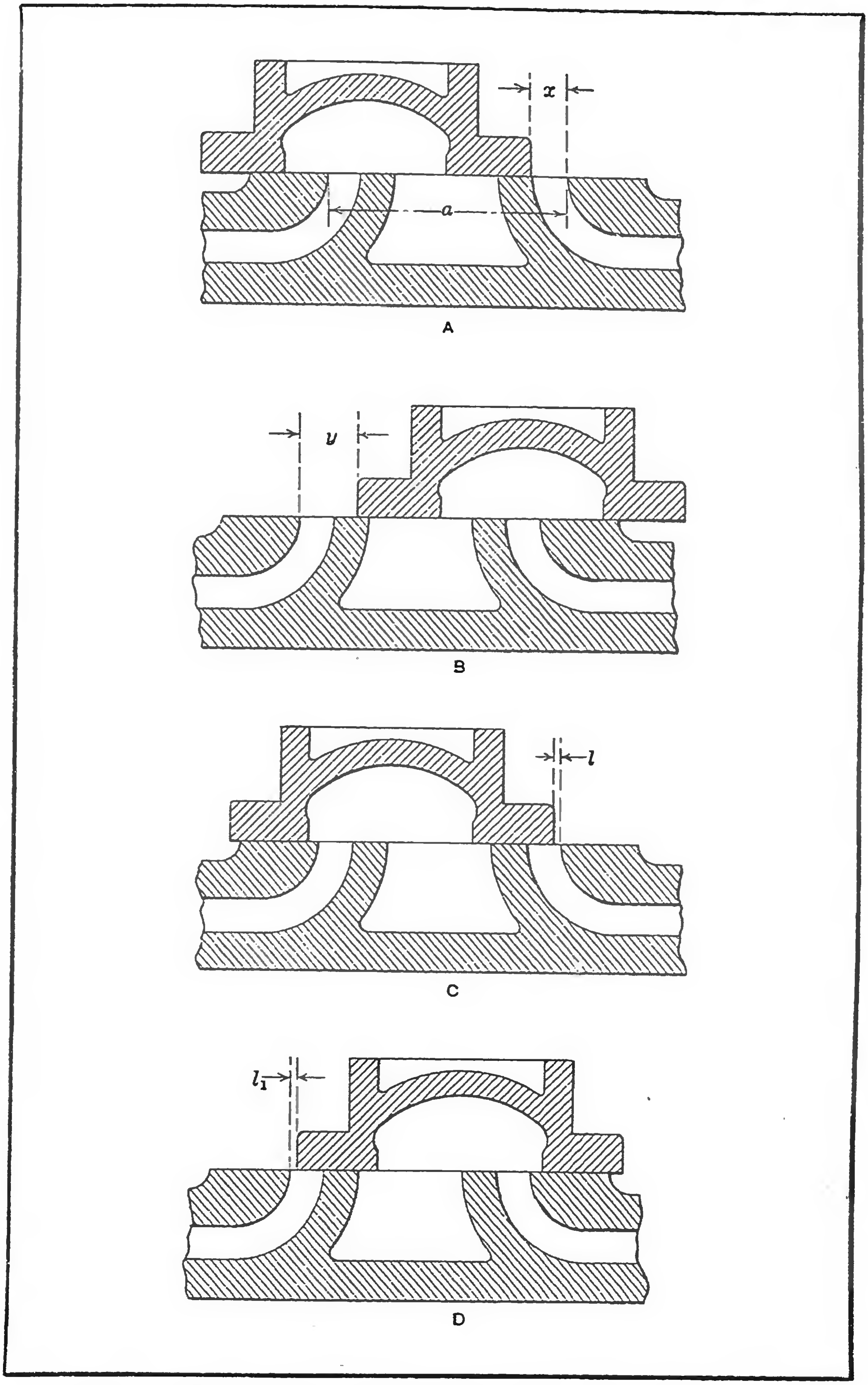


Fig. 2. Slide Valves in Different Positions with Reference to Cylinder Ports

caused by the angularity of the connecting rod is downward, and, therefore, taken directly by the bed or frame of the engine, which is desirable.

Assume, in this case, that the engine is to run over; then, if the motion is direct, the eccentric rod being connected with the valve-stem so that the movement of the valve-stem is not reversed but in the same direction as the eccentric rod (as in Fig. 1), the eccentric should be located on the shaft so that a line passing through the centers of the crankshaft and eccentric will be 90 degrees ahead of the center-line of the crankpin, plus a small amount due to the lap of the valve, as explained in the next paragraph. The eccentric will then *lead* the crankpin when the engine is running; consequently, the position of the eccentric indicates the direction in which the engine will rotate. On the other hand, if the eccentric rod is connected to the valve-stem by a rocker arm, which gives the valve-stem a reverse movement (the motion being indirect), the eccentric should be so set that its center-line is a little *less* than 90 degrees back of the crankpin, the eccentric following the crankpin when the engine is in motion.

Adjustment of Eccentric for Lead: After setting the eccentric approximately 90 degrees either ahead or back of the crank, the position depending upon the desired direction of rotation, as previously explained, place the engine on one of the dead centers. Next turn the eccentric about the shaft until there is a port opening equal to the amount of lead l required (see illustration *C*, Fig. 2). A valve is given *lead* or initial port opening at the beginning of the piston stroke so that the clearance space in the cylinder will be filled with steam. Ordinarily, the lead varies from 1/32 to 3/16 inch, for stationary engines, 1/16 inch being a fair average. The amount is sometimes determined by experiment after the engine is erected. When there is little or no lead, the tendency is for the piston to move under reduced pressure through part of its stroke, especially if the ports are rather small and the clearance space fairly large. A small amount of lead may give good results, especially when the compression is sufficient to produce a pressure at the beginning of the stroke nearly equal to the boiler pressure. Naturally a quick-acting valve requires less lead than one which opens more slowly.

Having adjusted the eccentric so that the valve uncovers one port an amount equal to the lead required, turn the engine until it is on the opposite dead center; this will cause the valve to move to the position shown at *D*, Fig. 2, so that the lead l_1 or port opening on the opposite side can be measured. If the valve travel was carefully equalized, the measurements l and l_1 should be the same. If they are not equal, the eccentric rod or valve-stem will

have to be lengthened or shortened sufficiently to move the valve an amount equal to one-half the difference between l and l_1, in whatever direction is necessary. The eccentric should then be readjusted to give the lead required.

After setting the eccentric to give the required amount of lead, it is firmly secured to the crankshaft. On small engines, this is often done by simply tightening set-screws, whereas, on larger sizes, the eccentric is held more securely by the addition of a key, the keyway in a new eccentric being cut after its location has been determined. It is good practice to test the position of the valve after the eccentric has been securely fastened in place. If the valve was not given lead or initial port opening, and it did not have outside lap, the total width being equal to distance a, sketch A, Fig. 1, the eccentric would then be set at right angles to the crankpin. Slide valves are given outside lap, however, so that the steam will be cut off before the piston stroke is completed, and be used expansively, thus securing greater economy.

Effects of Changes in Lap: An increase of the outside lap means an earlier cut-off and greater expansion, and it naturally follows that decreasing it means a later cut-off and decreased expansion. On the other hand, increasing the inside lap increases compression and delays the point of release, whereas reducing the inside lap decreases compression and gives an earlier release. The amount of inside lap, however, has no effect upon the position of the eccentric and, therefore, does not directly affect the setting of the valve. An early cut-off means an early compression, and the latter becomes excessive when the cut-off takes place at about two-thirds of the stroke; therefore, a plain slide valve is seldom designed to cut off earlier than two-thirds or three-fourths of the stroke, except in the case of high-speed engines and locomotives.

Effect of Connecting-rod on Point of Cut-off: The points of admission and cut-off of a steam engine should properly occur at corresponding points in the forward and return strokes of the piston. When a valve is set as described in the foregoing, the admission of steam will occur just before the piston reaches each end of its stroke. If an indicator were applied to the steam cylinder, however, the card would show that the points of cut-off for the forward and return strokes were not equal. If the engine were running over, the cut-off would be later on the forward stroke than on the return stroke. (The piston is on the *forward stroke* when moving toward the crank end of the cylinder, whereas the reverse motion toward the head end is known as the *return stroke.*) This is due to the fact that the valve was set with relation to the rotation of the crank and not with reference to the movement of the piston.

In a crank motion, the relative positions of the piston and crankpin vary throughout the stroke. During the forward stroke, the piston moves ahead of the crank, or, in other words, it passes the center of its stroke before the crankpin has turned ¼ revolution. Inversely, on the return stroke, the piston lags behind the cross-head, and, when it reaches the mid-position of the stroke, the crankpin has turned farther than ¼ revolution. The reasons for these variations in the relative movement of the crank and piston are as follows: When the cross-head and attached piston reaches the center of the forward stroke, the crankpin has not turned ¼ revolution, owing to the angularity of the connecting-rod. When the crankpin has moved 90 degrees, or ¼ revolution, the cross-head and piston have passed the central position. On the return stroke, the crankpin reaches its mid-position before the cross-head and piston. The result of this variation between the movements of the crankpin and piston is that, when a valve has an equal amount of lap on both sides, it will admit and cut off steam at equal crank angles, but the positions of the piston for the forward and return strokes will not be alike. The cut-off will occur too late on the forward stroke and too early on the return stroke, steam being admitted for a longer time to the head end of the cylinder than to the crank end.

Equalizing Cut-off by Changing Outside Lap: One way of overcoming this difficulty and equalizing the cut-off is to give the valve more outside lap on the side adjacent to the head end of the cylinder, in order to hasten its action, and reduce the lap on the other side to allow the piston to travel farther before the steam is cut off. Inasmuch as the piston travels ahead of the crank when moving toward the crank end of the cylinder, it naturally follows that, if the valve is given more lap on the head end, the steam will be cut off earlier. It must be remembered, however, that equalizing the cut-off by varying the lap of the valve causes an unequal amount of lead or initial port opening at the ends of the stroke, because adding to the lap at the head end must, of necessity, delay admission, whereas the reverse effect is obtained at the crank end.

Inequality of lead is usually considered by engineers a more serious disadvantage than inequality in the points of cut-off, and, therefore, slide valves are usually designed with an equal amount of outside lap on each side. When setting a valve of this kind, a compromise is sometimes made by lengthening the valve-rod enough to reduce the lead at the head end, thus partially equalizing the point of cut-off. As will be apparent, if the valve, instead of traveling centrally over the ports, is moved somewhat toward the head end, thus reducing the lead, the steam will be cut off earlier, overcoming, in part, the irregularity due to the

connecting-rod. This adjustment affects the point of release, but tends to equalize the compression.

Setting the Slide Valve for Equal Cut-off: In case it is desired to set a slide valve in such a way that the cut-off will occur at equal points in the travel of the piston, this may be done by the following method: Begin by turning the engine until the cross-head has moved, say, from the head end to the point where it is desired to have the steam cut off. Then loosen the eccentric and turn it about the shaft until the valve closes the port leading to the head end of the cylinder. After tightening the eccentric upon the shaft, continue turning the engine until the cross-head has passed the opposite dead-center position and traversed a distance from the crank end equal to the distance at which the cut-off is desired, which should correspond for the forward and return strokes. Upon examining the position of the valve relative to the steam port, it will be found that it is not at the point of cut-off, owing to the irregularities inherent in a crank motion. In order to adjust the valve for equalizing the cut-off, move it one-half the distance necessary to cause cut-off, by changing the length of the valve-rod or stem; then adjust it for the other half of the required distance by changing the position of the eccentric on the shaft. By changing both the valve rod and eccentric each one-half the required amount, the cut-off at the head end will remain unchanged while the cut-off at the crank end will be made to occur at the required point. After making these adjustments, it is well to check the accuracy of the work by again placing the engine at the point of cut-off for the head end of the cylinder.

Setting Valves on Reversible Engine: When an engine is equipped with a reversing mechanism of the shifting-link type illustrated by the diagrams, Fig. 1, the valve is set in practically the same way as described in the foregoing, except that it must be adjusted for the forward and backward motions, and, instead of a single eccentric, there are two eccentrics which must be located with reference to the crankpin. The procedure, in brief, is as follows: The travel of the valve is first equalized with the reversing link set for one direction of rotation, as illustrated at *A*, and also for the reverse motion, or with the link raised, as at *B*, the lengths of each eccentric rod *f* and *b* being varied as may be required. When these adjustments have been made, and the valve travels an equal distance each way from its central position for both forward and backward motions, the eccentrics are set to give the required amount of lead or initial port opening. The procedure is the same as described for a non-reversing engine, except that care should be taken to have the link in the forward position when adjusting the forward eccentric, and in the backward position when adjusting the eccentric for that di-

rection of rotation. The eccentric which is controlling the movement of the valve *leads* the crankpin, if the motion is direct (as illustrated in Fig. 1), whereas the eccentric *follows* the crankpin if the motion is indirect.

Use of Indicator for Valve Setting: The action of an engine valve and its control of the admission and release of steam to and from the cylinder may be shown graphically by means of the steam engine indicator. To one accustomed to reading indicator diagrams, any errors in the design or adjustment of the valve are apparent. In fact, the indicator is frequently used in connection with the valve-setting operation, in order to secure an accurate adjustment and good control or distribution of the steam. The indicator not only shows defects in the valve adjustments, but indicates leaky pistons or valves and other defects.

What would be considered a good indicator card depends somewhat upon the type of engine, its speed, and the design of the valve and valve-operating mechanism. The card shown at *A*, Fig. 3, is a theoretical form and might be considered ideal for one type of non-condensing engine. The admission of steam begins at *a* and usually just before the piston reaches the end of its stroke, provided the valve is given lead or initial port opening. This is what causes the sudden rise of the line from *a* to *b*, the rise indicating an increase in steam pressure. The admission of steam continues from *b* to *c*, and then the steam is cut off by the valve, as indicated by the gradual down-slope of the line, which shows the reduction of pressure due to the steam expansion in a space which increases in volume, owing to the movement of the piston. At point *d*, the exhaust valve opens so that there is a rapid fall of pressure represented by the curve *de*. During the return stroke, the steam is forced out of the cylinder through the exhaust port and under a slight back pressure, as shown by the line *ef*, which is a little above the atmospheric line. At point *f*, the exhaust port is closed by the valve, and compression begins, thus causing the pressure to rise as shown by the curve *fa*. Steam is then admitted to the cylinder and the cycle repeated.

In actual practice, the indicator is connected by pipes with each end of the cylinder, so that diagrams showing the action of the steam in both ends are drawn upon the same card, the diagram for the opposite end occupying the position indicated by the dotted lines. The different parts of the indicator diagram are ordinarily given the following names: *bc* is the steam line; *cd*, the expansion line; *de*, the release; *ef*, the back-pressure line; *fa*, the compression; *ab*, the admission. By applying an indicator to a steam engine, when taking diagrams, the effect of the valve action on the control of the steam is apparent to one accustomed to reading these diagrams. For instance, the diagram

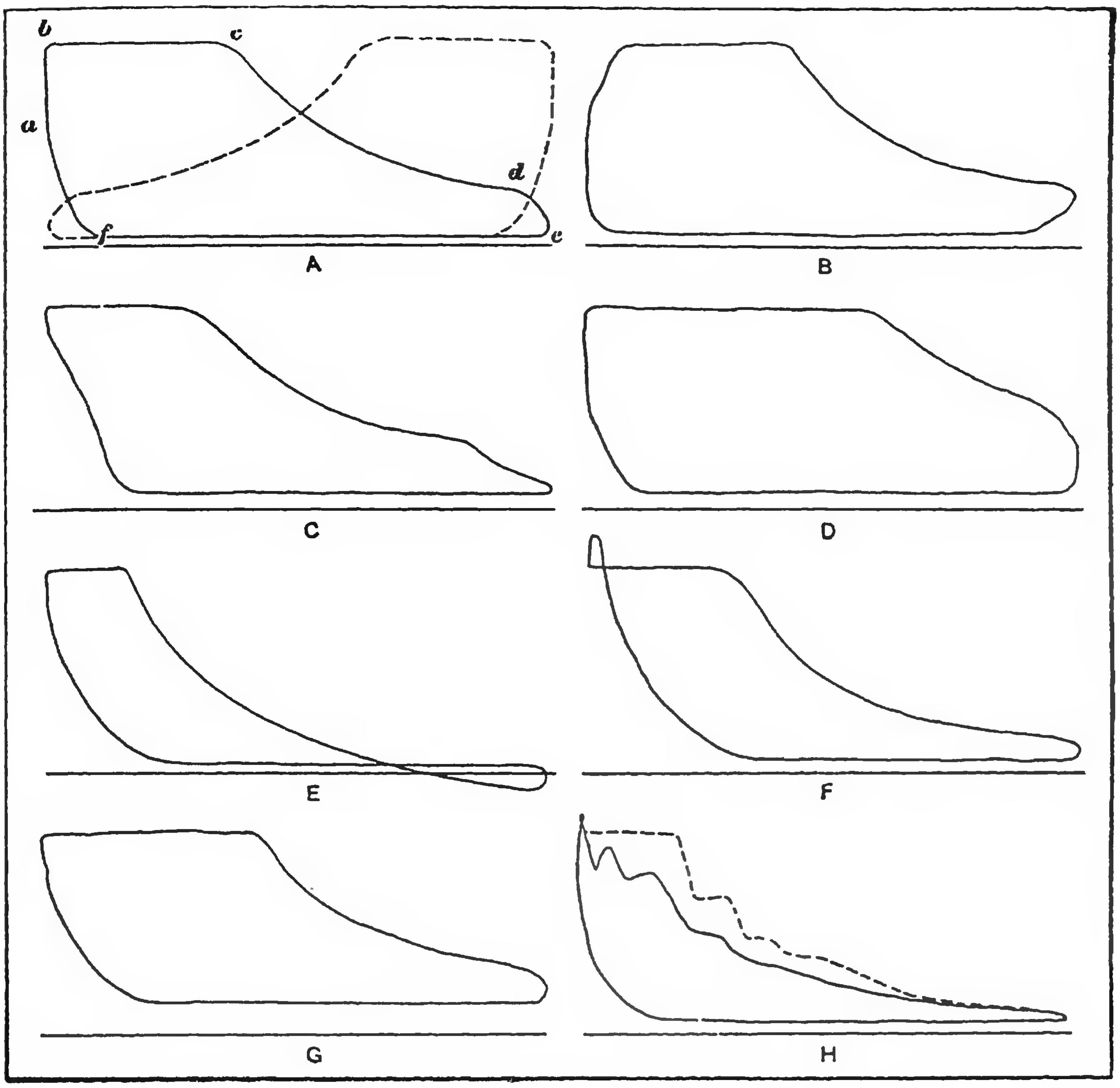


Fig. 3. Indicator Cards showing Defects in Valve Adjustment, and Other Causes of Incorrect Diagrams

shows whether the points of admission, cut-off, and release of the steam occur at the proper time, and also whether or not the compression is excessive. Defects may be due to incorrect adjustment or setting of the valves or to the use of a valve which is not properly proportioned.

Indicator Diagram Showing Late Admission: Diagram *B*, Fig. 3, shows the effect of admitting steam too late or after the piston has passed the dead-center position. This is indicated by the fact that the admission line (corresponding to line *ab*, diagram *A*) curves forward instead of being approximately square with the atmospheric line. The remedy is to change the position of the eccentric with relation to the crankpin, so that the valve will open the port just before the piston reaches the end of its stroke or before it passes the dead-center position. When a valve is improperly adjusted, as shown by this diagram, it also affects the timing of other events in the cycle of movements of the valve.

For instance, in this case the admission of steam occurs too late; consequently, the opening of the exhaust port or the point of release is also too late, as shown by the backward slope of the release curve corresponding to *de*, diagram *A;* moreover, the closing of the exhaust port or the point of compression is also too late; thus there is too little compression.

Diagram Showing Early Admission: Diagram *C*, Fig. 3, shows that the steam was admitted to the cylinder too early in the stroke, the result being that the admission line (corresponding to line *ab*, diagram *A*), instead of being nearly square with the atmospheric line, inclines backward, thus showing that the port was opened considerably before the piston reached the end of its stroke. With an ordinary slide valve, all of the other events are also effected, the cut-off, release, and compression being too early. The remedy in this case is to change the position of the eccentric. For the same type of engine, the eccentric would be moved in a direction opposite to that required for correcting the error shown by diagram *B*. In the case of diagram *B*, if the engine were equipped with an outside-admission slide valve and a direct motion, the eccentric would be moved farther away from the crankpin, whereas, in the case of diagram *C*, it would be moved toward the crankpin.

Cut-off Too Late: Diagram *D* shows that the steam was cut off too late, this being indicated by the length of the horizontal steam line at the top of the diagram. The result is that the steam is not expanded sufficiently, and the terminal pressure at the end of the stroke is entirely too high, so that considerable steam is wasted. A diagram of this kind indicates that the valve does not have sufficient outside lap. In fact, if it were made without any outside lap, steam would be admitted for the full length of the stroke, and the card would be nearly rectangular in form.

Cut-off Too Early: The other extreme is shown by diagram *E*, since in this case the cut-off occurred too early in the stroke. The result was that the steam expanded down to zero and then the continued movement of the piston caused the formation of a partial vacuum, as indicated by the loop which extends below the atmospheric line. The compression also occurs too early and is excessive, as shown by the curve corresponding to *fa*, diagram *A*. The remedy in this case is to reduce the amount of outside lap on the valve, thus causing the cut-off to occur later. Incidentally, when computing the mean effective pressure of a diagram of this kind, for obtaining the horsepower of the engine, the area of the loop below the atmospheric line should be subtracted from the area of the remaining part of the card.

Excessive Compression: Excessive compression is shown by the diagram *F*. As will be seen, the compression begins some

time before the piston approaches the end of its stroke, with the result that the pressure of the entrapped steam exceeds the boiler pressure, as indicated by the loop formed at the top of the diagram. A card of this kind indicates that the inside lap is excessive and should be decreased so that the exhaust port will not be closed too soon. The required amount of compression depends somewhat upon the type and the speed of the engine, slow-running engines requiring less compression than those of high speed. In any case, however, the compression should not exceed the initial or boiler pressure. It is considered good practice to compress to about nine-tenths the initial pressure for high-speed engines, one-half the initial pressure for engines of medium speed, and from two-tenths to three-tenths the initial pressure for slow speed engines. Whenever a loop is formed in this way, its area should be deducted from the area of the diagram, when computing the mean effective pressure. By comparing diagrams *A* and *F*, it will be apparent that there is considerable loss in power in the case of diagram *F*, owing to the excessive compression, which illustrates the importance of using valves that are properly designed and set.

Diagram *G* indicates excessive back pressure, since the back-pressure line (corresponding to *ef*, diagram *A*) is too far above the atmospheric line. This indicates that the exhaust port is too small, the result being that considerable pressure is required to force the steam out of the cylinder. When the exhaust steam is used for heating purposes, and has to be pushed through coils of pipe, this might cause a similar diagram.

Wavy Lines in Diagrams: In actual practice, the diagrams are frequently not as well defined as those illustrated, especially when taken from engines operating at high speeds. In fact, they are liable to be deranged considerably, owing to oscillations of the piston and pencil motion. An example illustrating the effect of these oscillations is shown at *H* (see full line). With a diagram of this kind, it is difficult to determine the exact point of cut-off, although the error in the mean effective pressure obtained from such a diagram is not very great, and, in many cases, is negligible. The fact remains, however, that more accurate diagrams are obtained from comparatively slow-speed engines. Another source of error which sometimes causes incorrect diagrams, or those which do not properly show the action of the steam, is that due to friction of the indicator piston. Even though an indicator is in perfect condition when applied to the engine, it may become fouled by burnt oil or other material from the steam cylinder, which causes excessive friction. When the piston of the indicator does not move freely, a diagram is often obtained which resembles the one shown, in part, by the dotted lines at *H*. The line is

formed of rather straight sections and its direction changes rather abruptly, giving the card a zigzag formation.

Valve Travel. The total distance that an engine slide valve moves in one direction is known as the *travel.* This term is used instead of the word "stroke," which might properly be applied.

Vanadium. Vanadium is a light colored metal having a specific gravity of from 5.5 to 6. It melts at a temperature of 1750 degrees C. (3182 degrees F.). Its specific heat at 32 degrees F. is 0.124, and its electrical conductivity (silver = 100) is about 5; it is non-magnetic. Vanadium is widely distributed in small quantities in a large number of minerals. It is an important alloying metal used in steel, vanadium steel having a number of valuable properties which are not obtainable in ordinary steel. On account of its great affinity for carbon, oxygen, and nitrogen at high temperatures, absolutely pure vanadium has not been produced. Owing to its very high melting point, vanadium, even if it were commercially possible to produce it reasonably pure in the metallic state, would present much difficulty in alloying with other metals. Fortunately, it is relatively easy to reduce vanadium as an alloy of iron, ferro-vanadium, containing approximately one part of vanadium and two parts of iron. This alloy has a melting point of about 1300 degrees C. (about 2370 degrees F.), which is low enough for it to melt and alloy readily when added to molten steel.

Vanadium Steel. The two most marked characteristics of vanadium steel are its high tensile strength and its high elastic limit. Another equally important characteristic is its great resistance to shocks; vanadium steel is essentially a non-fatigue metal, and, therefore, does not become crystallized and break under repeated shocks like other steels. Tests of the various spring steels show that, when subjected to successive shocks for a considerable length of time, a crucible carbon-steel spring was broken by 125,000 alternations of the testing machine, while a chrome-vanadium steel spring withstood 5,000,000 alternations, remaining unbroken. Another characteristic of vanadium steel is its great ductility. Highly-tempered vanadium-steel springs may be bent sharply, in the cold state, to an angle of 90 degrees or more, and even straightened again, cold, without a sign of fracture; vanadium-steel shafts and axles may be twisted around several complete turns, in the cold state, without fracture. This property, combined with its great tensile strength, makes vanadium steel highly desirable for this class of work, as well as for gears which are subjected to heavy strains or shocks upon the teeth. Chromium gives to steel a brittle hardness which makes it very difficult to forge, machine, or work, but vanadium, when added

to chrome-steel, reduces this brittle hardness to such an extent that it can be machined as readily as an 0.40-per-cent carbon steel, and it forges much more easily. Vanadium steels ordinarily contain from 0.16 to 0.25 per cent of vanadium. Steels of this composition are especially adapted for springs, car axles, gears subjected to severe service, and for all parts which must withstand constant vibration and varying stresses. Vanadium steels containing chromium are used for many automobile parts, particularly springs, axles, driving-shafts, and gears.

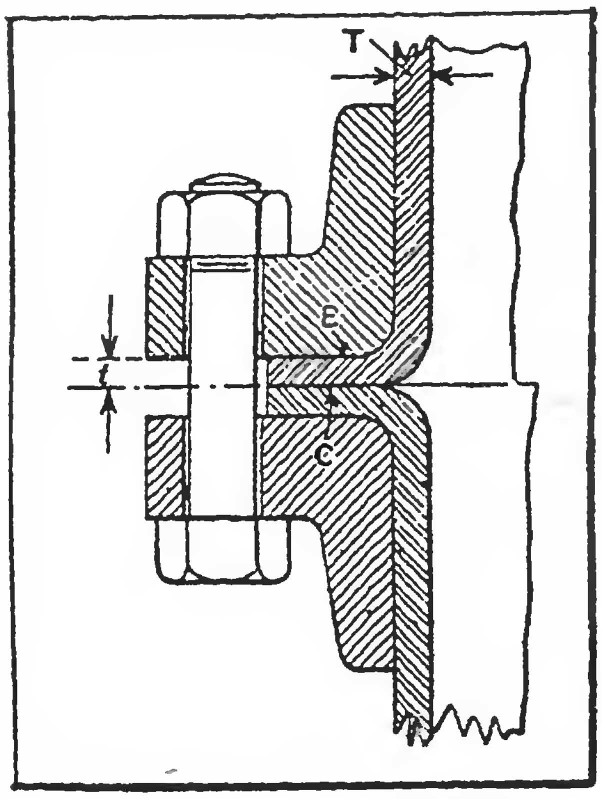
Van Dyke Prints. Van Dyke negatives have white lines on a brown background. If positive prints are desired or those having either blue or brown lines on a white background, they may be obtained in the following manner: The original tracing is first used to make a negative copy on thin Van Dyke paper. This copy will have white transparent lines on an opaque dark brown background. Another print is then made by using this Van Dyke negative in place of the original tracing, and the result is a positive print which will have dark lines on a white background if Van Dyke paper is used, or blue lines on a white background if regular blueprint paper is used. Similar results may also be obtained on cloth by using either prepared blueprint cloth or Van Dyke cloth, depending upon whether a blue-line or a brown-line print is desired.

Vanishing Thread Joint. A vanishing thread joint is a pipe joint made up of a tapered pipe thread screwed into a tapered thread socket. The taper of the thread is the standard pipe thread taper of ¾ inch to the foot; the only difference lies in the fact that the thread is carried to the vanishing point instead of ending abruptly.

Vanite. An alloy that has the following composition: tungsten, 18 per cent; chromium, 4 per cent; vanadium, 2 per cent and carbon and iron, the balance. It is a high-speed steel that is used for cutters and tools used in conjunction with such machine tools as lathes, milling machines, and planers.

Van Stone or Rolled Joint. The original form of Van Stone pipe joint, commonly referred to as a *rolled joint,* due to the fact that the pipe is rolled or lapped over the face of the flange is shown by the illustration. In making this and similar types of rolled joints, the flange is bored out to fit loosely over the end of the pipe, after which the pipe end is heated in a furnace to the required temperature and then lapped or rolled over the face of the flange as shown at *B*, the outer edge of the lapped portion of the pipe coming just inside of the bolt holes, as indicated. The rolling or lapping of the pipe is accomplished by the use of spe-

cial machinery designed especially for that purpose. In making Van Stone joints in a steam main, any good metallic or vulcanized gasket suitable for high-pressure super-heated steam may be used. Flanges for rolled joints can be made of cast iron, cast steel, or forged steel, depending upon the service for which the joints are intended. Rolled or forged steel flanges should always be given the preference over cast iron or cast steel for high-pressure service and where superheated steam is to be conveyed. Cast-iron flanges should not be used on steam mains for pressures above 150 pounds per square inch.



Van Stone or Rolled Joint

Vapor. This term is often used to designate gases in general, but it is usually restricted to the gaseous form of substances that at ordinary temperatures and pressures are liquids or solids.

Vapor Lamps. Vapor lamps consist of glass bulbs or tubes containing electrodes and some kind of rarefied gas that becomes luminous when an electric current is passed through it. The gas may be neon, argon, kripton, xenon, or mercury vapor. The electrodes between which the current passes may be of different types and varying distances apart.

The emission of light in this type of lamp is theoretically explained by the ionization of the gas and the emission of electrons from the cathode. In the cold cathode type of lamp, the ionized gas particles bombard the cathode and electrons are consequently driven off or released. In the hot cathode type of lamp, the electronic emission is obtained thermally, that is by heating of the cathode.

High-voltage, cold cathode lamps or luminous tubes are filled with one of the rare gases just mentioned and operate in a voltage range extending from 2000 to 15,000 volts. This necessitates the use of a specially designed luminous tube transformer to supply current at the required high potential. Usually, these lamps are in the form of tubes of varying lengths which are shaped into letters or decorative designs for advertising and display purposes. When the gas used is neon, a characteristic reddish-orange light is produced; argon gives a purple light; krypton, a pale violet; xenon, a green; and mercury vapor, a blue light.

Low-voltage, cold cathode lamps often called Neon-glow lamps, are commonly provided with a screw-type base and a built-in resistance which restricts power consumption to from about ¼ watt to 2 watts on 110-125-volt circuits. The electrodes are placed quite close together and the light emitted is of low intensity so that these lamps are suitable mostly for signalling or indicating purposes.

One type of *hot cathode lamp* utilizes a pool of mercury as a cathode. Passage of current through the lamp produces a hot spot on the surface of the mercury which results in the emission of electrons and the production of mercury vapor. The lamps are usually in the form of tubes varying in length from 25 to 50 inches, with other sizes used for special purposes.

A *high-intensity mercury vapor lamp* has recently been introduced to operate on regular lighting circuits. Because its starting voltage is around 240 volts and operating voltage is about 155 volts, a high-reactance transformer is also needed. Mercury vapor lamps are used as a source of ultra-violet light. The tubes are of fused silica or quartz-glass.

One type of mercury lamp used as an ultra-violet light source utilizes both a mercury arc and a tungsten filament. The latter, when heated, starts the mercury arc and also supplies a small percentage of the light.

Hot cathode neon lamps operate satisfactorily at 125 volts direct current. They are used for advertising and display purposes, as well as for signal beacons.

Sodium vapor lamps utilize a sodium vapor to produce a bright yellow light which has been found especially suitable for street and highway high-intensity illumination.

Variance. This term is used to represent the amount by which the readings of an instrument vary in successive indications of the same value of the measured quantity. Variance may be due to lost motion; friction; changes due to the stress-strain relation of springs in the force-resisting or restoring element of the instrument; changes in the distribution of parts, as variation of position of pins in bearings or variation in the amount of liquid retained on wetted surfaces. There may also be other factors of less importance.

Varnish, Pattern. See Pattern Varnish or Shellac.

Vector. A vector is a straight line of given length and specified direction. It is used in the graphical analysis and solution of problems in mechanics, where it represents such elements as force, velocity and acceleration, and in alternating-current electricity where it represents such elements as current, voltage, and reactance. All of these elements have direction as well as magni-

tude, whereas *scaler* elements such as weight and temperature have magnitude only.

Vegetable Glue. See Glues for Wood.

Velocity. Velocity is distance divided by time or the rate of motion in a unit of time, and is expressed in feet per second, feet per minute, miles per hour, etc. Velocity may be either *absolute* or *relative*. The absolute velocity of a body is its velocity with reference to some object which is considered completely at rest; the relative velocity of a body is its rate of motion with relation to another moving body. In considering velocity in practical mechanics, the earth is assumed to be stationary, so that the velocity of any moving body, as, for example, a moving train with relation to the rails, would be absolute velocity, but a person walking through the train would move with a certain relative velocity with reference to the train, and with an absolute velocity with reference to the road-bed over which the train moves. If two trains moving in opposite directions, at a speed of 50 miles an hour, pass each other, they have each an absolute velocity of 50 miles an hour, but the relative velocity between the two trains would be 100 miles. If two trains, one of which has a speed of 40 miles an hour and the other 25 miles an hour, move in the same direction, and the faster train passes the slower, the relative velocity of the faster train with reference to the slower will be 15 miles an hour, but its absolute velocity is 40 miles an hour.

Velocity Head. Velocity head is the force, causing a gas or liquid to flow through a pipe line, which is due to the velocity of the gas or liquid.

Velocity Pressure. Velocity pressure is the working pressure which actually forces a fluid or gas through a discharge opening and which equals the difference between the dynamic pressure and the static pressure.

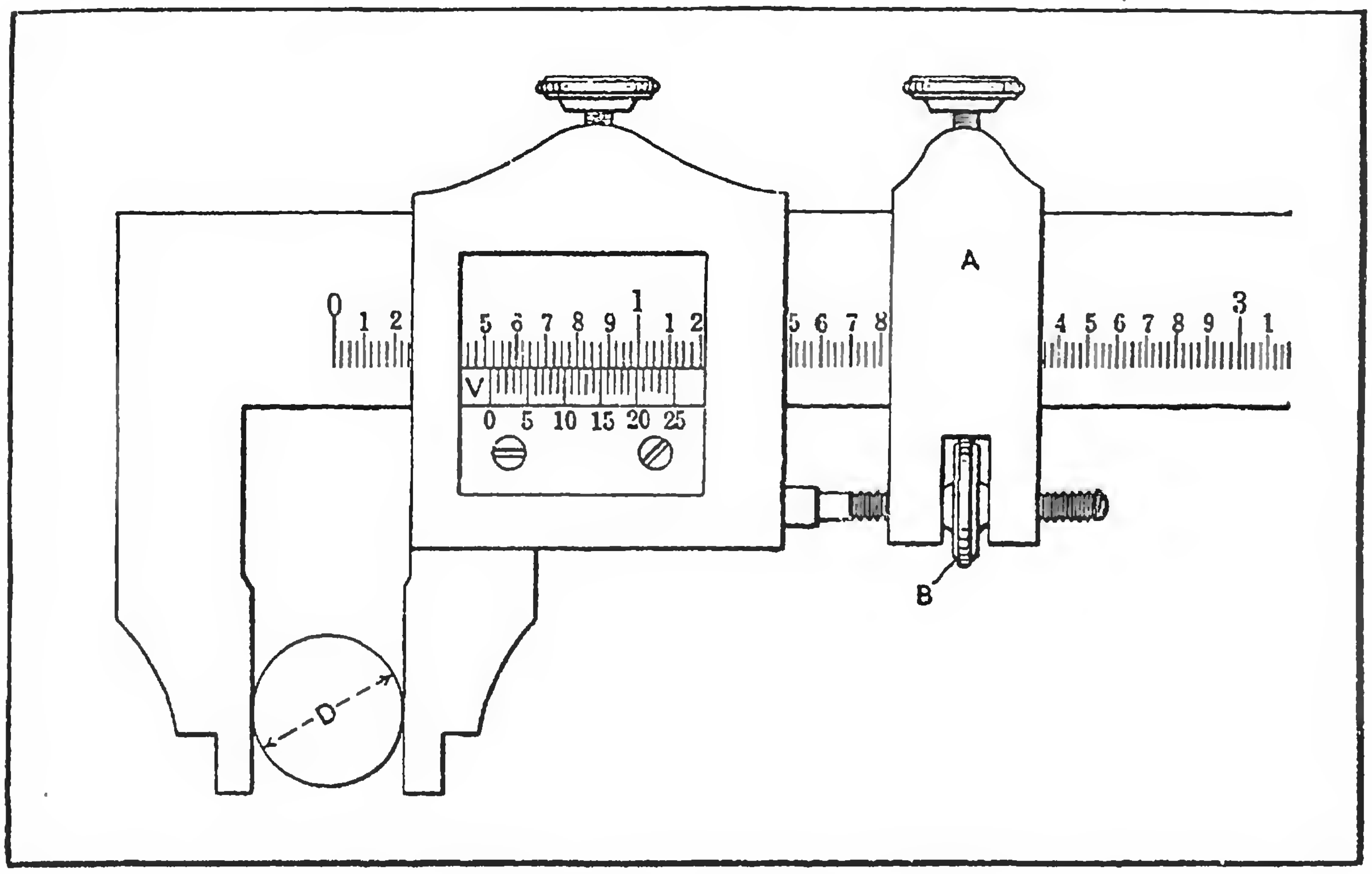
Veneer Glue. See Glues for Wood.

Venting. In core making, venting is the process of providing outlets for gases so that they may escape when the molten metal is poured into the mold.

Venturi Meter. The Venturi meter is an instrument for accurately measuring the discharge of fluid or gas through a pipe. The meter consists essentially of an hour-glass shaped section of pipe with smoothly rounded internal walls into which two gages are fitted, one at a point where the pipe is of full diameter, and

one at the smallest section or opening in the pipe. By means of the pressure recorded by the two gages and the use of certain constants that have been calculated for various diameters of pipe, the discharge through the pipe may be determined.

Vernier Calipers and Scale. The vernier is an auxiliary scale that is attached to vernier calipers, height gages, depth gages, protractors, etc., for obtaining the fractional parts of the subdivisions of the true scale of the instrument. The true or regular scale of the vernier calipers shown in the illustration, is graduated in tenths of an inch, each tenth being divided into



Vernier Calipers

four parts, or in fortieths of an inch, but by means of the vernier scale *V*, which is attached to the sliding jaw of the instrument, measurements within one-thousandth of an inch can be taken. The vernier, in this case, makes it possible to divide each fortieth of an inch on the true scale into twenty-five parts. To measure the diameter *D* with a vernier calipers, note the distance that the vernier scale zero has moved to the right of the zero mark on the true scale. This dimension may be read directly in thousandths of an inch, by calling each tenth on the true scale that has been passed by the vernier zero, one hundred thousandths, and each fortieth, twenty-five thousandths, and adding to this number as many thousandths as are indicated by the vernier. The vernier zero in the illustration is slightly beyond the five-tenths division; hence, the reading is 0.500 plus the number of thousandths indi-

cated by that line on the vernier that exactly coincides with one on the scale, which, in this case, is line 15, making the reading $0.500 + 0.015 = 0.515$ inch.

Rule for Reading a Vernier: The following is a general rule for taking readings with a vernier: Note the number of inches and whole divisions of an inch that the vernier zero has moved along the true scale, and then add to this number as many thousandths, or hundredths, or whatever fractional part of an inch the vernier reads to, as there are spaces between the vernier zero and that line on it which coincides with one on the true scale.

In order to determine the fractional part of an inch that may be obtained by any vernier, multiply the denominator of the finest subdivision of an inch given on the true scale by the total number of divisions on the vernier. For example, if the true scale is divided into fortieths and the vernier into twenty-five parts, the vernier will read to thousandths ($40 \times 25 = 1000$). If there are sixteen divisions to the inch on the true scale and a total of eight on the vernier, the latter will enable readings within one hundred twenty-eighths of an inch to be taken ($16 \times 8 = 128$). It will be seen then that each subdivision on the true scale can be divided into as many parts as there are divisions on the vernier.

Vernier of Retrograde Form. This is a vernier in which the divisions of the vernier are larger than the divisions on the main scale. Generally the divisions on verniers are made smaller than the divisions on the main scale, and such verniers are known as *direct.*

Vertex. The vertex of an angle is the point where the two lines forming the angle intersect.

Vertex Distance. The vertex distance of a bevel gear is the distance measured in the direction of the axis of the gear from the corner of a tooth at the large end to the vertex of the pitch cone. The vertex distance at the small end of the tooth is similarly measured.

Vertical Boring Mill. This type of machine tool, commonly referred to as a "boring mill," has a circular table which revolves about a vertical axis so that the work-holding surface is horizontal, thus making it comparatively easy to place in position and hold large circular castings such as flywheels, cast-iron covers, etc. See Boring Machines.

Vertical Turret Lathe. Machines called vertical turret lathes are similar in their general design to a vertical boring mill which has a side head. See Turret Lathe Classification.

Vibracork. Material consisting of pure cork compressed into boards of uniform quality and density. Does not deteriorate or disintegrate, but will last in its original state for years. A cork foundation for machinery makes it possible to operate equipment quietly, with freedom from vibration. Used as a foundation for motors, engines, fans, blowers, pumps, printing presses, generators, elevator machinery, etc.

Vibration Due to Steam Flow. Steam, when flowing at a high velocity in the supply pipe of a high-speed engine, is alternately stopped and raised again to this high velocity several hundred times a minute, due to the rapid opening and closing of the steam valves. This intermittent motion of the steam has, in many cases, been found to cause vibration in the engine supply pipe, which, in turn, is transmitted to other branches of the system. Vibration is also caused by suddenly changing the direction of steam flow through tees and short-turn elbows, and sometimes by the unequal velocity of steam flowing through different branches of the piping system. Vibration, combined with expansion and contraction strains, is a constant source of danger. The pipe should be so proportioned that the velocity will be as nearly uniform as possible in all branches of the system. The engines should be equipped with steam separators of large capacity to cushion the steam, at or near the engine throttle, and the piping should be firmly anchored at suitable points.

Vibration of Structures. Every part of a building—beams, floors, columns, walls, etc., in fact the entire building itself—has its natural pitch of periodic number of vibrations which will result when it is set in motion. If the cause be intermittent and of a different frequency from that of the structural features, the result will be a breaking up of vibrations except for those intervals when they get in step; then the natural action will be exaggerated. The effect of coincidence between the natural frequency of vibration of a floor and that of its source of disturbance is well illustrated by the following experience in connection with the testing of a small engine upon a floor of timber construction. At a speed of about 550 revolutions per minute, the intensity of the floor vibration was so great that it was impossible to work in the drafting-room located on the same floor more than 100 feet away; but this effect entirely disappeared when the speed was either increased or decreased about 50 revolutions per minute. When the disturbing force is represented by a number of machines running at practically the same speed, the effect may be like that of dancers upon a floor or soldiers marching over a bridge, and prove destructive to the entire structure if the step time coincides with its natural pitch.

Vibroscope. The vibroscope is an apparatus which is used in examining rapidly moving mechanisms in order to study the causes of extreme vibration or other operating characteristics. By means of this apparatus a rapidly moving part appears stationary. A special electric lamp is used to illuminate the moving part by a series of instantaneous flashes so timed that the part under observation is only lighted when in whatever position it is to be observed. This succession of flashes occurs so rapidly that the part appears to be stationary, or if desired, it can apparently be given a slow motion similar to the effect of a slow-motion moving picture, merely by a gradual change between the flashes and the position of the moving member. The vibroscope consists (1) of a lamp containing a special Neon tube of unusual design, which gives illumination far in excess of that ordinarily obtained in any vacuum tube, and at the same time, the flash is of extreme rapidity; (2) means of supplying the electrical discharges to illuminate the tube; and (3) a device for regulating the flashes of light in synchronism with the movements of the mechanism under examination. The light flashes are controlled by an interruptor which is preferably driven direct from a shaft of the mechanism under observation so that the flashes will automatically be in synchronism with the movement of the mechanism. Rotary movement is imparted to the shaft of the interruptor through the medium of a steel or rubber driving point which is held in contact with the center on the shaft of the machine under examination; or if necessary, a direct coupling may be arranged. A cam is mounted on the interruptor shaft which operates a contacting device. The interruptor is in two parts, one of which may be rotated concentrically upon the other. On turning the outer part, the timing of the flashes is changed; thus if it is turned in the direction of rotation, the part under observation will appear to move forward slowly when viewed under the rays of the light, and similarly, if it is turned in the opposite direction, the part will appear to rotate backward. Hence, the mechanism may apparently be brought to rest in any desired position in the cycle of operations.

When the switch is turned on, the light will flash at the same speed as the rotation of the shaft, and any of the moving parts of the machine that are brought under the rays of the light will immediately appear stationary, irrespective of whether the motion is rotary, reciprocating, or vibratory, provided the drive for the interruptor is rotary. Above a certain speed the flashes are woven into a continuous picture. Direct rays of daylight from a window may cause some inconvenience, but screening of these rays is all that is necessary. If a vibrating part is illuminated with flashes at twice its frequency, the interruptor can be set

so that the vibrating part is viewed simultaneously in its two extreme positions; in other words, a double image of the vibrating part will be shown and from the distance apart of the two images, a measurement of amplitude can be obtained. See also Stroboscope.

Vickers Hardness Test. The Vickers test is similar in principle to the Brinell test. The standard Vickers penetrator is a square-based diamond pyramid having an included point angle of 136 degrees. The numerical value of the hardness number equals the applied load in kilograms divided by the area of the pyramidal impression. A smooth, firmly supported, flat surface is required. The load, which usually is applied for 30 seconds, may either be 5, 10, 20, 30, 50 or 120 kilograms. The 50-kilogram load is usually employed. The hardness number is based upon the diagonal length of the square impression. The Vickers test, which is considered very accurate, may, with proper load regulation, be applied to thin sheets as well as to larger sections.

Vinco. A high-speed steel used to make milling cutters, reamers, and twist drills. It has the following composition: carbon, 0.65 to 0.73; manganese, 0.15 to 0.30; chromium, 3.75 to 4.25; vanadium, 0.85 to 1.0; tungsten, 17.5 to 18.5 per cent; iron, the balance.

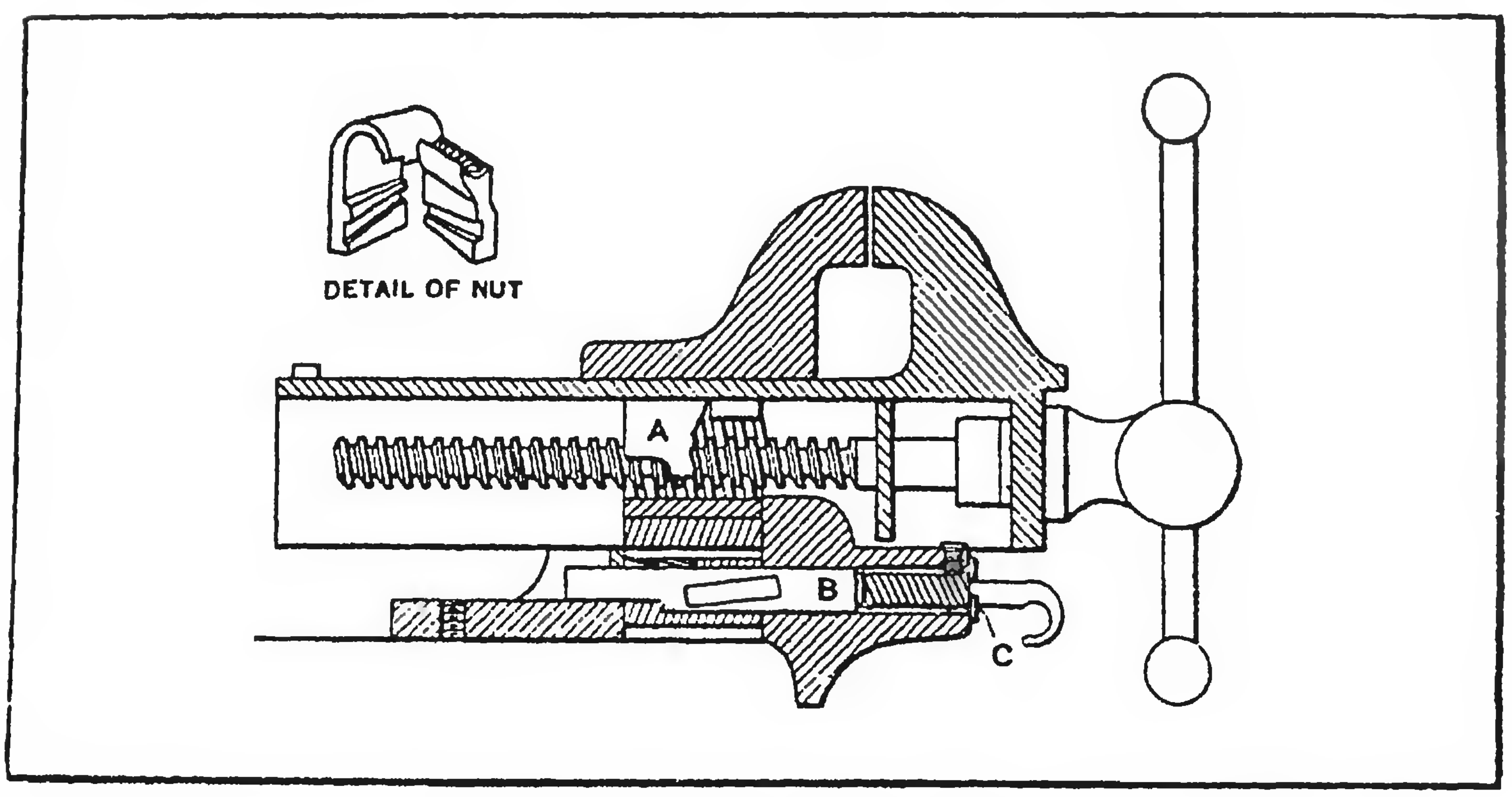
Virgin Copper. Virgin copper, also known as malleable copper and native copper, is found in nature practically pure, having all the properties of refined metal. Virgin copper is mined extensively in the Lake Superior district in the United States, and also in Bolivia.

Viscosity of Oils. The viscosity of an oil or other fluid is the resistance offered to a flowing movement, or the fluidity, which is affected by the internal friction and resulting variations in the relative motion of the particles. As the temperature of oils rises, the viscosity decreases. Animal or vegetable oils maintain their viscosity better than those of mineral origin. Mineral oils lose their viscosity with a rise of temperature more rapidly than the fixed oils (animal or vegetable), but the difference between the two classes of oils, in this respect, diminishes considerably for temperatures above 100 degrees F. (or 150 degrees F., in the case of cylinder oils). Experiments were undertaken to determine the relation between viscosity and the wearing and lubricating qualities of oils, and the effect of the constituents of various oils on the lubricating qualities. Twenty-two oils were

tested, the method of procedure being to find the chemical composition and viscosity of each oil, and then use it as a lubricant in a journal bearing. The experiments showed that the viscosity of an oil affects its lubricating quality in the following way: If the oil is adapted to the load put upon it, then the lower the viscosity, the better the oil as a lubricant. The oil, however, must conform to the character of the load, a light oil being unsuitable for heavy loads.

Vises. Clamping and holding tools called *vises* are used in machine shops for many purposes, both in connection with bench work and for holding parts on machine tools. For general hand-fitting operations, vises are usually fastened to a bench. *Machine vises* are used in milling, drilling, and other machining operations instead of special jigs or fixtures, and on some classes of work requiring high production and rapid operation, special jaws of suitable form are used. Vises of this kind are operated either by a screw or by means of a link and cam controlled by a hand lever, the latter type having largely superseded the former in interchangeable manufacture.

The illustration shows an example of a *quick-acting vise*, which is so constructed as to permit a rapid adjustment of the jaws. In this design, a nut *A*, formed of two pieces (as shown in detail in the upper part of the illustration), is either opened or closed on the operating screw by means of the operating bar *B* which has two tapered tongues as indicated. By means of these tongues, one-half of the nut is moved upward and the other downward, for releasing it from the screw. The operating bar is provided with a ratchet catch *C*, which when engaged, holds the nut open during adjustment. The illustration shows the nut disen-



Quick-acting Machinist's Vise

gaged from the operating screw, and the jaw, therefore, free to be moved as desired. Another type of quick-acting vise employs a lever at the side of the vise, which, by means of a toggle action, engages a dog with a ratchet which is cut on the side of the slide, and thus moves and locks the jaws. Approximate adjustments are quickly made by hand in this type of vise by sliding the jaw in or out.

Vise, Universal Ball. See Universal Ball Vise.

Vitrified Grinding Wheels. The term "vitrified" denotes the type of bond used in these grinding wheels. The bond in a grinding wheel is the material which holds the abrasive grains together and supports them while they cut. With a given type of bond, it is the *amount* of bond that determines the "hardness" or "softness" of wheels. The abrasive itself is extremely hard in all wheels, and the terms "hard" and "soft" refer to the *strength of bonding;* the greater the percentage of bond with respect to the abrasive, the heavier the coating of bond around the abrasive grains and the stronger the bond posts, the "harder" the wheel.

Most wheels are made with a vitrified bond composed of clays and feldspar selected for their fusibility. During the "burning" process in grinding wheel manufacture, the clays are fused into a molten glass condition. Upon cooling, a span or post of this glass connects each abrasive grain to its neighbors to make a rigid, strong, grinding wheel. These wheels are porous, free cutting and unaffected by water, acids, oils, heat, or cold. Vitrified wheels are extensively used for cylindrical grinding, surface grinding, internal grinding and cutter grinding.

Volt. The unit of electromotive force is known as the volt. The volt is the electromotive force which, when steadily applied to a conductor the resistance of which is one ohm, will produce a current of one ampere.

The electromotive force between the poles or electrodes of the voltaic cell known as the Weston normal cell, at a temperature of 20 degrees C. (68 degrees F.), which is 1.0183 volts, is used as a reference standard.

Voltages Commonly Used. For lighting circuits and most power circuits either 115 or 230 volts is the customary nominal voltage at the point of utilization. Some industrial plants also make use of 440-volt circuits for heavy motor drives.

For primary distribution of power to the points of utilization the following nominal voltages are customary: 2,300; 4,000; 4,600; 6,600; 11,000 and 13,200.

For transmission of power in large quantity, voltages extend over a much wider range and depend in part upon the length of the transmission line. By stepping-up the transmission voltages. the currents are proportionately reduced and consequently the losses due to heating of the conductors, which vary with the square of the current, are kept at a minimum. The customary transmission voltages are: 13,200; 22,000; 33,000; 44,000; 66,000; 110,000; 132,000; 154,000 and 220,000.

Voltameter. The voltameter is a device in which the passage of a current through a solution produces a chemical effect which can be measured. In one of its oldest forms, the current decomposes water into its gaseous elements, oxygen and hydrogen, the volume of which, collected in a test tube, forms a measure of the average current strength. In the *silver voltameter* used in laboratories as a primary standard for determining current strength, the weight of silver deposited from a solution in a given time is a measure of the average current value during that time.

Volta's Pile. This term refers to a means for transforming chemical energy into electrical energy employed by Volta in 1799, consisting of alternate disks of zinc and copper with a wet cloth or blotting paper between the disks.

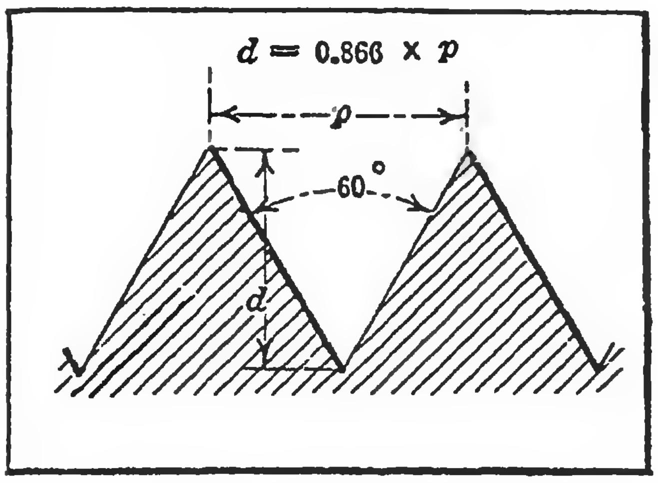
Voltmeter. A voltmeter is an electrical measuring instrument which is used to indicate the potential difference between any two points in an electrical circuit to which its terminals are connected.

Voltmeters are made in types which are basically similar to ammeters, i.e., electrodynamic types which have a fixed coil and a moving coil; permanent magnet types which have a fixed permanent magnet and a moving coil; moving-iron types which have a fixed coil and a moving iron or vane; thermocouple types with junctions of different metals which supply a direct current when heated that causes the pointer to indicate the voltage being measured; electrostatic types which have fixed and moving metal parts that are attracted or repelled by electric charges; and electronic types utilizing electronic tubes. The electronic type is of comparatively recent development.

In many cases, built-in or external resistances are connected in series with voltmeters to act as multipliers and so extend their measuring range. Thus, a voltmeter having a scale that reads 0 to 10 volts may be made to read directly 0 to 100 volts or some other multiple of the original scale values by using the proper multiplier. Sometimes separate scales are provided for each range.

Volumetric Efficiency. In air compression, volumetric effi-

ciency is the ratio of the actual volume of air taken into the cylinder per stroke to the piston displacement. It varies with the amount of clearance and with the terminal pressure. It is usually 90 per cent or over in the best classes of machines, but may fall considerably below this figure in the case of small machines of poor design and construction.



Sharp V-thread

V-Thread. The top and bottom or root of this thread form are theoretically sharp (see illustration), but in actual practice the thread is made with a slight flat, owing to the difficulty of producing a perfectly sharp edge and because of the tendency of such an edge to wear away or become battered. This flat is usually equal to about one twenty-fifth of the pitch, although there is no generally recognized standard. Owing to the difficulties connected with the V-thread, the tap manufacturers agreed in 1909 to discontinue the making of sharp V-thread taps, except when ordered. One advantage of the V-thread is that the same cutting tool may be used for all pitches, whereas, with the American Standard form, the width of the point or the flat varies according to the pitch. The V-thread is regarded as a good form where a steam-tight joint is necessary, and many of the taps used on locomotive work have this form of thread. The sides of the thread form an angle of 60 degrees with each other. If p = pitch of thread, and d = depth of thread, then:

$$d = p \times \cos 30 \text{ deg.} = 0.866\, p = \frac{0.866}{\text{No. of threads per inch}}.$$

The American Standard screw thread is used largely in preference to the sharp V-thread because it has several advantages. See American Standard Screw Thread System.

Vulcanite Grinding Wheels. The abrasive grains of vulcanite wheels are bonded by the use of vulcanized rubber. Very hard, tough, thin wheels can be produced. Vulcanite wheels, like those of the elastic type, are made very thin, and are adapted for cutting off tubing, wire, thin sheets of steel or brass, and parts that are difficult to hold for cutting by regular tools. For general cutting-off operations, when the speed of cutting is not an important factor, vulcanite wheels are generally considered preferable to elastic wheels. The latter, however, can be used to better advantage for cutting off tempered tool steel or alloy steel tools, when cool cutting is important, because of their softer grades and cooler grinding action.

W

Wahl Factor. This factor, which is used in helical or coiled spring design, was developed by A. M. Wahl, of the Westinghouse Electric & Mfg. Co., to compensate for errors found to result when stresses in helical springs were computed by formulas which take into account torsional stress only. Stresses in a loaded helical spring, due to transverse shear, tension and compression are of considerable magnitude, particularly when the ratio of mean diameter of spring to diameter of wire is low. This ratio is known as the "spring index." If $D =$ mean diameter of spring and $d =$ wire diameter, then the spring "index" $C = D \div d$.

$$\text{Wahl factor} = \frac{4C - 1}{4C - 4} + \frac{0.615}{C}$$

As the index ratio decreases, the Wahl factor increases. This factor, when applied as a multiplier to the computed torsional stress in a helical spring, gives a close approximation to the total stresses developed.

Walschaerts Valve Motion. The Walschaerts valve-gear which has been used extensively on locomotives, is so arranged that the valve receives its motion from two sources: the cross-head and an eccentric crank. The Walschaerts gear is more accessible than the Stephenson motion in that it is applied outside the wheels and requires only a single eccentric return crank and a connection to the cross-head for its operation. The eccentric crank may be a comparatively small pin attached to the main crank, and it does the work of the two heavy eccentrics of the ordinary gear. This arrangement leaves the entire space between the frames clear for bracing the frames. The Walschaerts gear as compared with the Stephenson, causes a more uniform steam distribution with a lower percentage of preadmission, to which is added a constant and moderate amount of lead for early cut-off, although on the resultant economy in steam consumption there can be but slight difference when both the gears are in a first-class condition.

Warding File. A warding file has parallel faces, that is, it is of the same thickness throughout, but it is tapered in width for the whole length from the heel to the point. It is generally

double-cut, and is used by jewelers and machinists, but especially by locksmiths for filing "ward notches" in keys; hence, the name "warding file."

Washburn & Moen Wire Gage. This gage is the same as the American Steel & Wire Co's. gage, which, as approved by the Bureau of Standards at Washington, is now known as the "Steel Wire Gage." This gage applies to all steel wire, and is used to a greater extent than any other steel wire gage in the United States. See Gages for Wire.

Washed Metal. Washed metal is a name used for cast iron from which most of the silicon and phosphorus have been removed, by the so-called "Bell-Krupp process," without removing much of the carbon contents, so that the metal still contains enough carbon (over 2.2 per cent) to be classified as cast iron.

Washers. Plain washers are made in standard sizes to suit standard screw threads, bolts and screws. The manufacturers' regular standard, adopted in 1935, is for bolt sizes ranging from ¼ inch up to 3 inches, inclusive. There is also an S.A.E. standard for plain washers. This includes screw and bolt sizes ranging from No. 2 machine screw up to, and including, 1½-inch bolts. These washers are somewhat smaller than the manufacturers' standard and also have smaller inside diameters or clearance spaces between the bolt and washer.

Wash-Out Taps. Mud and wash-out taps are used in boiler work, the same as taper boiler taps and patch-bolt taps. These taps are sometimes referred to as *arch pipe taps*, but the former name is the more common. They taper 1¼ inch per foot, and have 12 threads per inch. The thread form may be either the American Standard or the sharp V-thread.

Waste, Cotton and Woolen. There are two principal classes of waste. One class is intended for cleaning purposes and the other for holding a lubricant, as, for example, when used as a packing material in the journal boxes of railway cars or in some classes of motor bearings. The various grades of cotton waste comprise the first class, whereas wool waste comprises the second class, which is used as packing. The cotton or cleaning waste is by far the most important commercially, if judged by the extent of its use. The most essential property of waste is its oil-absorbing quality. Poor waste is soon saturated with oil or grease, whereas good waste will absorb much more oil and may be turned inside out and used again. A high absorbing quality is desirable both in cotton and wool waste, but the importance of this feature might easily be overlooked, especially in the case of waste used exclusively for cleaning purposes. To

obtain a waste capable of absorbing the greatest amount of oil and grease, it is essential, in the first place, to use the right kinds of raw materials and, second, to mix these materials thoroughly and separate the various threads or fibers completely, so that there are no solid masses or large thick strands extending through the waste.

Waste Reclamation. Oily and otherwise soiled waste and wiping cloth can be reclaimed at about 20 per cent of the cost of new material. The process of reclamation can be repeated from ten to thirty times, according to the quality of the material. The apparatus consists mainly of a washing machine used in connection with drying machines.

Water Brakes. All the power absorbed by a Prony brake is transformed into heat. When the amount of power to be absorbed is considerable, the Prony brake becomes unsatisfactory for the reason that it is impossible to conduct away such enormous quantities of heat, and avoid temperatures which will be destructive both to the pulley and to the brake. In such cases, some form of water brake is generally used. A water brake usually consists of a casting in which disks or paddles revolve and churn or agitate a quantity of water contained in the casing. The disks or paddles are fixed to a shaft which delivers the power to be obsorbed. The casing is free to turn about the shaft, and an arm extending from it rests upon some form of weighing apparatus. Vanes or ribs fixed to the casing prevent the water from turning with the rotating member. The same formulas are employed in computing the power absorbed as are used in the case of a Prony brake. In order to carry off the heat generated, the water which is agitated is allowed to flow away and is continuously replenished by fresh cold water. The power absorbed by a brake of this type depends upon the speed and upon the quantity of water which is agitated. Other things being equal, the power absorbed is approximately proportional to the cube of the number of revolutions per minute.

Water Flow Measurement See Weir; also Flow Meter.

Water Gas. See Gas Production.

Water Glass. This is a glass tube used on steam boilers to indicate the height of the water level in the boiler. It consists mainly of a vertical tube mounted into pipes connecting with the boiler. The lowest visible part of the glass tube should be not less than 2 inches above the lowest permissible water level.

The term "water glass" is also applied to a substance consisting of silicates of sodium or potassium, or of both. The com-

mercial form of water glass may be a stony powder, a glassy mass, or, when dissolved in water, a viscous syrupy liquid.

Water Pressure. The greatest density of water occurs at 39.1 degrees F., when it weighs 62.425 pounds per cubic foot. The pressure in pounds per square inch of water that is not moving, against the sides of any pipe, vessel, container, or dam is due solely to the "head" or vertical height of the surface of the water above the point at which the pressure is considered. The pressure is equal to 0.433 pound per square inch for every foot of the head, at a temperature of 62 degrees F. For higher temperatures, the pressure decreases slightly. The pressure per square inch is equal in all directions, downward, upward, and sideways. Water is composed of hydrogen and oxygen, in the ratio of two volumes of the former to one of the latter. It boils under atmospheric pressure at 212 degrees F. and freezes at 32 degrees F. Water can be compressed only in a very slight degree, the compressibility being so slight that, even at the depth of a mile, a cubic foot of water weighs only about one-half pound more than at the surface. The quantity of water that will be discharged through a pipe in a given time depends primarily upon the head and also upon the diameter of the pipe, the character of the interior surface, and the number and shape of the bends.

Waterproof Compositions. The asphalt fluid coatings for reservoir walls, concrete foundations, brick, wood, etc., are often of use to engineers. Asphalt only partly dissolves in petroleum naphtha, but when heated in a steam-jacketed kettle and not thinned out too much, a mixture of the two may be obtained in which the part of the ashpalt not dissolved is held in suspension. Asphalt is entirely soluble in benzol or toluol, which are about the cheapest solvents for all the constituents of asphalt. Tar and pitch are sometimes used in this connection, but tar contains water, light oils, and free carbon, and does not wear as well as good refined asphalt; pitch also contains free carbon, which is sometimes objectionable when it is thinned out with a solvent. Asphalt alone is somewhat pervious to water, but it can be improved in this respect by adding about one-fourth its weight of paraffin; it is also well to add a little boiled linseed oil. For thicker compositions, where body is required, asbestos, stone powder, cement, etc., may be added as fillers. Lutes of linseed oil thickened with clay, asbestos, red or white lead, etc., are waterproof if made thick enough. These are much used for steam joints. Flaxseed meal made into a paste with water is often serviceable, the oil contained serving as a binder as the water evaporates.

Water Softening Plants. A water softening plant includes the necessary equipment for automatically removing the impurities from feed water before it enters the boilers. Water softening is carried on under two different conditions, known as the *cold* and *hot* processes, the former being again divided into the continuous and intermittent methods, which differ only in the way of handling the water and chemicals. The cold process is generally used where there is no convenient means at hand for heating the water, and where large quantities are to be treated. The chemicals most frequently employed are lime and soda solutions. These are added to the water automatically in the right proportions as determined by chemical analysis. The precipitates thus formed are allowed to settle in large tanks, or are removed by filtration, depending upon the form of apparatus used. In the hot process, soda ash is used the same as in the cold process, but the carbonates are precipitated by heating the water by means of exhaust steam.

Water Turbine. See Turbine, Water.

Water-Wheel. A water-wheel or water turbine may be defined as a prime mover in which the potential energy of a body of water is transformed into mechanical work. The water-wheel, also commonly called a *hydraulic motor*, is in its various forms one of the simplest devices for the development of power.

Hydraulic motors may be divided into three general classes: 1. Current and gravity wheels, which utilize either the impact of the current or the weight of the water. 2. Impulse wheels and turbines, which utilize the kinetic energy of a jet at high velocity. These are commonly employed in connection with a limited volume of water under a high head, which, in practice, may vary from 300 to 3000 feet. 3. Reaction turbines, which utilize both the kinetic energy and the pressure of the water. These are employed for conditions the reverse of those under (2), that is, with a large volume of water under a low or medium head. In practice, reaction turbines are used under heads ranging from 5 to 500 feet.

The available power in any given case depends upon the fall or *head*, and the *volume* of water. In case the water is utilized for the development of power by passing through a water motor, the efficiency of the latter must be taken into consideration. For approximate work, it is customary to assume an efficiency of 80 per cent, in which case the delivered or brake horsepower may be determined as follows: Multiply the cubic feet of water passing through the motor per minute, by the head, in feet; then divide the product by 661.

Watt. The watt is the unit of electrical power and, as recommended by the International Electrical Congress, in Chicago, 1893, and approved by Act of Congress, July 12, 1894, is equivalent to the work done at the rate of one joule per second. One watt also equals 0.001341 horsepower, or 0.7376 foot-pound per second. It is also equal to the energy required to move one ampere per second through a resistance of one ohm. One kilowatt is equal to one thousand watts.

Watt-Hour Meters. The motor-type of watt-hour meter is now in practically universal use wherever it is desired to ascertain the consumption or output of electrical energy. The dynamometer and the induction principles have been utilized in the motor elements, with eddy-current damping as the controlling force. Motor-type watt-hour meters may be classified as of the *commutator, mercury-motor,* and *induction* types. The latter can be used only on alternating-current circuits.

In each case, the speed of the rotating member or disk is proportional to the average power of the load to which the wattmeter is connected. Hence, the total number of revolutions made by the disk is proportional to the total energy which passes through the motor and, when used with properly calibrated scale, will cumulatively indicate the amount of electrical energy utilized in kilowatt hours.

The commutator and the mercury types, although capable of operation on alternating current, are now regarded as essentially direct-current meters, in view of the advantages of the induction principle for alternating-current work. The several types of watt-hour meters are built in various designs, according to their intended use, such as house, switchboard, and portable forms.

Wattmeter. A wattmeter is an electrical instrument used for measuring electric power. The power measured is the average value of the product of the instantaneous voltage by instantaneous current. Although the induction, electrostatic, hot-wire, thermo-couple and moving-iron types of instruments can all be adapted for use as wattmeters, the electrodynamic type is the most widely used.

In this type there are two coils: one of coarse wire, called the current coil, in series with the load which carries the current and one of relatively fine wire, called the potential coil, in series with a resistor which is connected in parallel with the load. The rotation of one coil—usually the potential coil—with respect to the other, which remains fixed, indicates the average power.

Wattmeters are used both as switchboard instruments and as portable instruments.

Wave-Form. The shape of the curve obtained when the instantaneous values of an alternating current are plotted against time in rectangular coordinates is the wave-form. The distance along the time axis corresponding to one complete cycle of values is taken as 2 π radians, or 360 degrees. Two alternating quantities are said to have the same wave-form when their ordinates of corresponding phase bear a constant ratio to each other. The wave-shape, as thus understood, is therefore independent of the frequency of the current and of the scale to which the curve is plotted.

Waviness. See Surface Finish.

Wax Impressions. A wax impression of a sample or model is sometimes required in the manufacture of articles made from metal. To make a wax impression, proceed as follows: Oil the surface, of which the impression is to be made, very slightly with a few drops of oil applied to a little waste. Then take common beeswax and melt it slowly, without boiling. Mix it with one or two tablespoonfuls of lampblack to half a tumbler of beeswax, and stir the mixture. In order to make the wax impression show up clearly, take a fine hair brush and brush a small amount of powdered graphite or rouge over the object of which the impression is to be made.

Wearing Value. This is a term used in the appraisal of manufacturing plants to designate the replacement value of equipment less the scrap value.

Wedge Coupling. A wedge coupling, also known as a vise coupling, is similar to a compression coupling which grips the two shafts to be connected with the wedging action. There are numerous designs, all of which employ some kind of a conical split inner sleeve.

Weighing Scale, Sensibility. See Scale Sensibility.

Weight and Mass. See Mass and Weight.

Weight, Effect of Altitude. See Gravity.

Weights and Measures Bureau. The present fundamental standards of length and mass for practically the whole civilized world result from the establishment of the International Bureau of Weights and Measures. In response to an invitation of the French government, fifteen countries, including the United States, sent representatives to a conference held in Paris in 1870, to consider the advisability of constructing new metric standards. This conference was of short duration, on account of the war

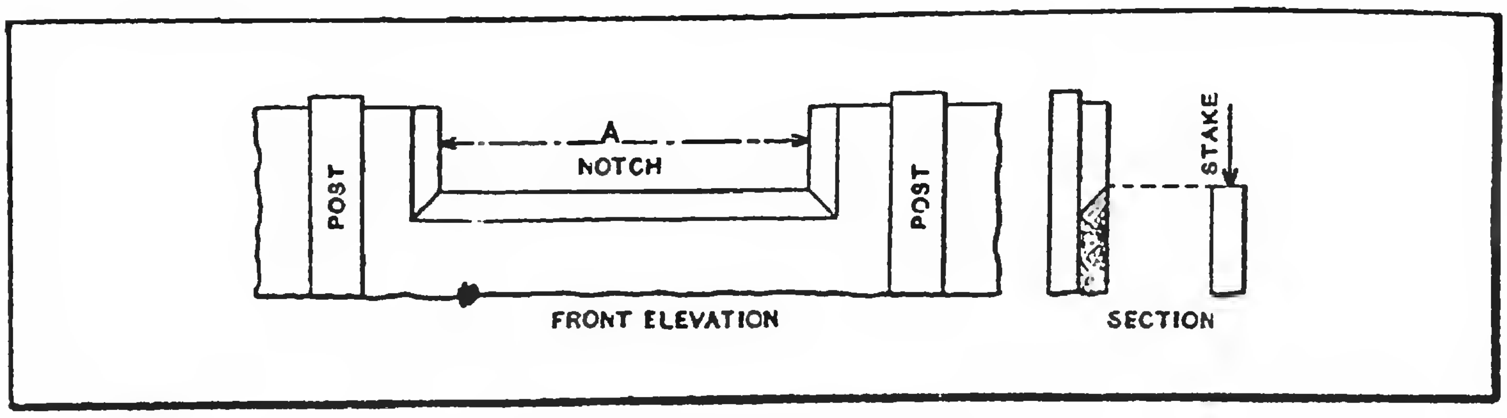
then raging between France and Germany. A second conference was held two years later, at which thirty countries were represented, the United States again being among this number. At this conference, it was decided that new meters and new kilograms should be constructed to conform with the original standards of the archives, and a permanent committee was appointed to carry out this decision. The preparation of the new standards had advanced so far by 1875 that the permanent committee, appointed by the conference of 1872, requested the French government to call a diplomatic conference at Paris to consider whether the means and appliances for the final verification of the new meters and kilograms should be provided, with a view to permanence, or whether the work should be regarded as a temporary operation. In compliance with this request, a conference was held in March, 1875, at which nineteen countries were represented, the United States being one of this number. In 1875, seventeen of the nineteen countries represented signed a convention which provided for the establishment and maintenance of a permanent International Bureau of Weights and Measures to be situated near Paris and to be under the control of an international committee elected by the conference, the committee to consist of fourteen members, all belonging to different countries.

In addition to the primary work of verifying the new metric standards, the bureau was charged with certain duties, the following being the most important: The custody and preservation, when completed, of the international prototypes and auxiliary instruments; the future periodic comparison of the several national standards with the international prototypes; the comparison of metric standards with standards of other countries. In accordance with the terms of the convention, the French government set aside a plot of ground just outside of Paris, and upon this ground, which was declared neutral territory, the International Bureau of Weights and Measures was established.

Weights, Atomic. See Atomic Weights.

Weir. A weir is used in conjunction with a table of constants to determine the flow of a stream in cubic feet per minute. For definite calculations of power, the flow of the stream must be measured under standard conditions. In the case of streams up to 40 or 50 feet in width, having a maximum depth of from 3 to 4 feet, the *weir* method is the simplest and the most accurate. The general construction of a weir dam is shown by the diagram. It should be so proportioned that all of the water will flow through a space the length *A* of which shall not exceed two-thirds of the width of the stream. The bottom and ends of the open section, or *notch*, as it is called, should be beveled on the

down-stream side, in order to give a sharp edge for the water to flow over. A short distance up-stream, a stake should be driven into the earth with its top on a level with the bottom of the notch. This may be done either by the use of a spirit level or by adjust-



Construction of Weir

ing the stake when the water has risen to a height just sufficient to spill over the weir. When the water has reached its full height, the depth above the bottom edge of the weir can be accurately measured by placing the end of a scale upon the top of the stake. If the measurement were made at the weir, it would be impossible to obtain an accurate result, owing to the curvature of the water as it flows over the edge.

In constructing a weir, it is important that the banks of the stream be parallel for a distance of several feet above it, and also that there be sufficient space at the sides, and sufficient depth below the notch, in order that the water may approach it quietly and without eddies.

The following figures represent, in the order given, the depth of water flowing over the weir and the equivalent number of cubic feet of water per minute passing over the weir for each inch of its length *A*. Depth 1 inch, cubic feet per minute, 0.40; 2 inches, 1.14 cubic feet; 3 inches, 2.08 cubic feet; 4 inches, 3.20 cubic feet; 5 inches, 4.48 cubic feet; 6 inches, 5.89 cubic feet; 7 inches, 7.41 cubic feet; 8 inches, 9.07 cubic feet; 9 inches, 10.81 cubic feet; 10 inches, 12.66 cubic feet; 11 inches, 14.62 cubic feet; 12 inches, 16.65 cubic feet; 13 inches, 18.77 cubic feet; 14 inches, 20.99 cubic feet; 15 inches, 23.27 cubic feet; 16 inches, 25.62 cubic feet; 17 inches, 28.08 cubic feet; 18 inches, 30.59 cubic feet; 19 inches, 33.16 cubic feet; 20 inches, 35.84 cubic feet; 21 inches, 38.55 cubic feet; 22 inches, 41.32 cubic feet; 23 inches, 44.19 cubic feet; 24 inches, 47.09 cubic feet.

Example: Assume that a weir has a notch 120 inches in length and the depth of the water passing through it as measured at the stake is 20 inches. What is the flow of the stream? According to the figures previously given, a depth of 20 inches is equivalent to a flow of 35.84 cubic feet per inch of weir width. Since the

total width equals 120 inches, the total flow equals 35.84 $\times$ 120 $=$ 4300 cubic feet per minute.

Welding. Welding, or more specifically fusion welding, may be defined as a group of processes in which metals are joined by bringing abutting surfaces to a molten state. Welding may be performed with or without the application of pressure and with or without the use of a filler metal. Heat may be provided by an electric arc, a gas flame, a chemical reaction, or the electrical resistance of the metals being joined to current passed through the joint.

The use of welding offers many advantages. It lends flexibility to machine designs. It facilitates lightweight construction and permits the use of standard rolled shapes. Standard shapes may be rolled or formed and joined with welding to cut costs by reducing material, machining, and finishing. As a joining process, it is used not only for fabrication, but also for the repair and maintenance of broken and worn parts. It requires relatively low capital investment costs.

Welding processes may be classified into the following broad categories: arc welding, gas welding, resistance welding, thermit welding, induction welding, and forge welding.

Welding Fluxes. In heating steel for welding, the tendency is for the surfaces to become oxidized, or covered with oxide of iron which forms a scale when the hot iron comes into contact with the air. If this scale is not removed, it will cause a defective weld. Wrought iron can be heated to a high enough temperature to melt this oxide so that the latter is forced out from between the surfaces by the hammer blows; but when welding machine steel, and especially tool steel, a temperature high enough to melt the oxide would burn the steel, and it is necessary to use a *flux*. This is a substance, such as sand or borax, having a melting temperature below the welding temperature of the work, and it is sprinkled upon the heated ends when they have reached about a yellow heat. The flux serves two purposes: It melts and covers the heated surfaces, thus protecting them from oxidation, and, when molten, aids in dissolving any oxide that may have formed, the oxide melting at a lower temperature when combined with the flux. Wrought iron can be welded in a clean, well-kept fire without using a flux of any kind, except when the material is very thin. The fluxes commonly used are fine, clean sand and borax. When borax is used, it will give better results if burned. This can be done by heating it in a crucible until reduced to the liquid state. It should then be poured onto a flat surface to form a sheet; when cold, it can easily be broken up and pulverized. The borax powder can be used plain or it

can be mixed with an equal quantity of fine clean sand and about 25 per cent of iron (not steel) filings. For tool steel, a flux made of 1 part of sal-ammoniac and 12 parts of borax is recommended.

Welding, Resistance Forge-. Resistance forge-welding is a process of heavy-duty electric resistance welding which enables the spot-welding of structural steel and iron sections formerly considered impossible to weld with conventional equipment. The method consists of first applying pressure to the work, then interrupted current, and finally superimposing a hammering action on the electrode. Under high pressure and with sufficient heat, the surfaces of the work are brought into intimate contact, so that when additional impact pressure and intermittent heat are applied, a forged weld of superior quality is obtained.

Weld Iron. According to the definitions adopted by the Brussels Congress of the International Association for Testing Materials, held in 1906, the expression "weld iron" designates the same kind and quality of iron as wrought iron, but the term is considered obsolete and needless in engineering nomenclature.

Weldless Chain. This is a chain in which the links are not welded, but simply bent in such a way that each link hooks firmly into the preceding link.

Weld Steel. This is iron containing enough carbon to harden if heated and suddenly cooled. The term "wrought steel" is also used.

Wells Process. The Wells process is a method for producing an oxide on iron or steel in order to protect it from the corrosive effects of the atmosphere. The process is similar in principle to the Bower-Barff process, except that the steam and producer gas enter the retort at the same time instead of being applied alternately. The result obtained by the Wells process is practically the same as that obtained by the Bower-Barff method.

Weston Brake. This is a mechanical brake where the braking action is created by the friction between a number of flat disks, and in which a spiral clutch or screw is used for automatically creating the required pressure between the disks.

Weston Cell. The Weston cell is a primary cell known as a standard cell, used to obtain a certain standard value of electromotive force under given conditions. There are actually two types of Weston cells.

The Weston *normal* or *saturated cadmium cell,* as it is sometimes called, is made up with a saturated cadmium sulphate solution, a positive electrode of cadmium amalgam and a negative electrode of mercury. This is the standard cell used at the Na-

tional Bureau of Standards in Washington and in other national agencies throughout the world as a primary standard of electromotive force. Its electromotive force is 1.0183 international volts at 20 degrees C. This is reproducible from cell to cell and remains practically constant for years, if proper care is taken. It has, however, an appreciable variation of electromotive force with temperature.

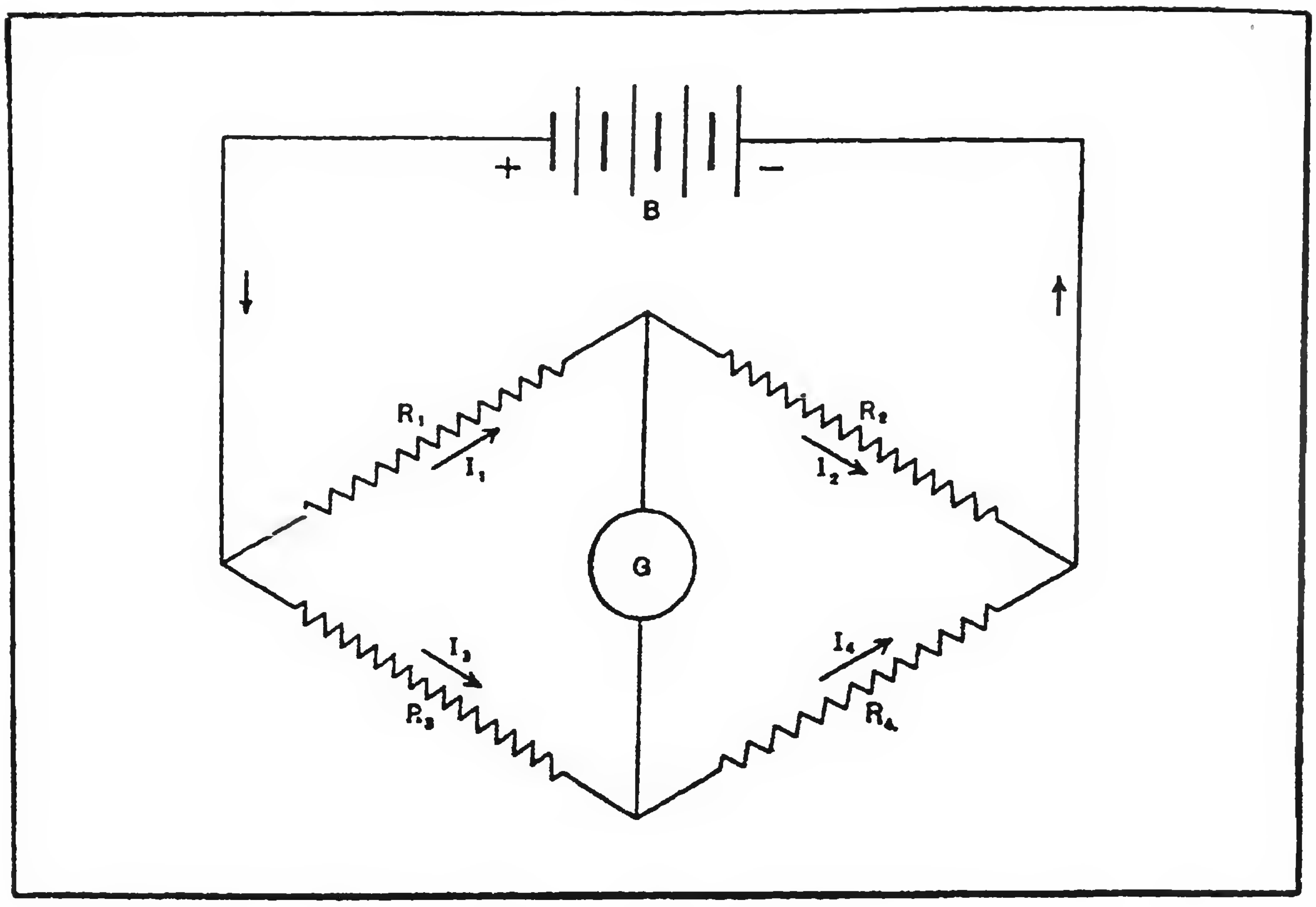
The Weston *secondary standard* or *unsaturated cadmium cell*, as it is sometimes called, is similar to the normal cell, except that no excess crystals of cadmium sulphate are present in the solution at ordinary temperatures as saturation is reached only when its temperature is reduced to 4 degrees C. It is a portable cell and finds wide use in engineering laboratories and industrial plants. The electromotive force of this type of cell usually falls between 1.0185 to 1.0195 international volts when new. It changes very little with temperature but decreases with age (about 25 to 50 microvolts per year) and use.

Weston Meter. A Weston meter is an ammeter used for measuring direct current only, in which a stationary permanent magnet acts upon a movable wire coil which is shunted by a low resistance.

Wet Cell. A wet cell is a primary cell in which the electrolyte is in the form of a liquid.

Wet Steam. Wet steam is saturated steam which contains more or less moisture in the form of spray. The percentage of dry steam in steam containing moisture is called the quality of the steam.

Wheatstone Bridge. The most generally used method for the measurement of the ohmic resistance of conductors is by the use of the *Wheatstone bridge*. In a simple form (see diagram) it comprises two resistance coils the ratio of the resistances of which is known, and a third, generally adjustable, resistance of known value. These are connected in circuit with the unknown resistance to be measured, a galvanometer, and a source of current, as in the diagram. The adjustable resistance and the "bridge arms," if necessary, are adjusted until the galvanometer indicates no flow of current. The value of the unknown resistance is thus measured in terms of the known resistance and the known ratio of the bridge arms. In the diagram, R_1, R_2, R_3, and R_4 are resistances, B a source of electromotive force, and I_1, I_2, I_3, and I_4 currents through the resistances; G is a galvanometer. If the relation of the various resistances is such that no current flows through G, then I_1 equals I_2, and I_3 equals I_4; also I_1R_1 equals I_3R_3, and I_2R_2 equals I_4R_4, there being no electromotive forces in the triangles R_1R_3G and R_2R_4G. It follows, therefore, that



Wheatstone Bridge

$$\frac{I_1}{I_3}=\frac{R_3}{R_1}, \text{ and } \frac{I_2}{I_4}=\frac{R_4}{R_2},$$

and hence, as

$$\frac{I_1}{I_3}=\frac{I_2}{I_4}, \text{ it follows that } \frac{R_3}{R_1}=\frac{R_4}{R_2}.$$

If one of these resistances, R_1 for instance, is unknown, it may then be found through the equation:

$$R_1=\frac{R_2R_3}{R_4}.$$

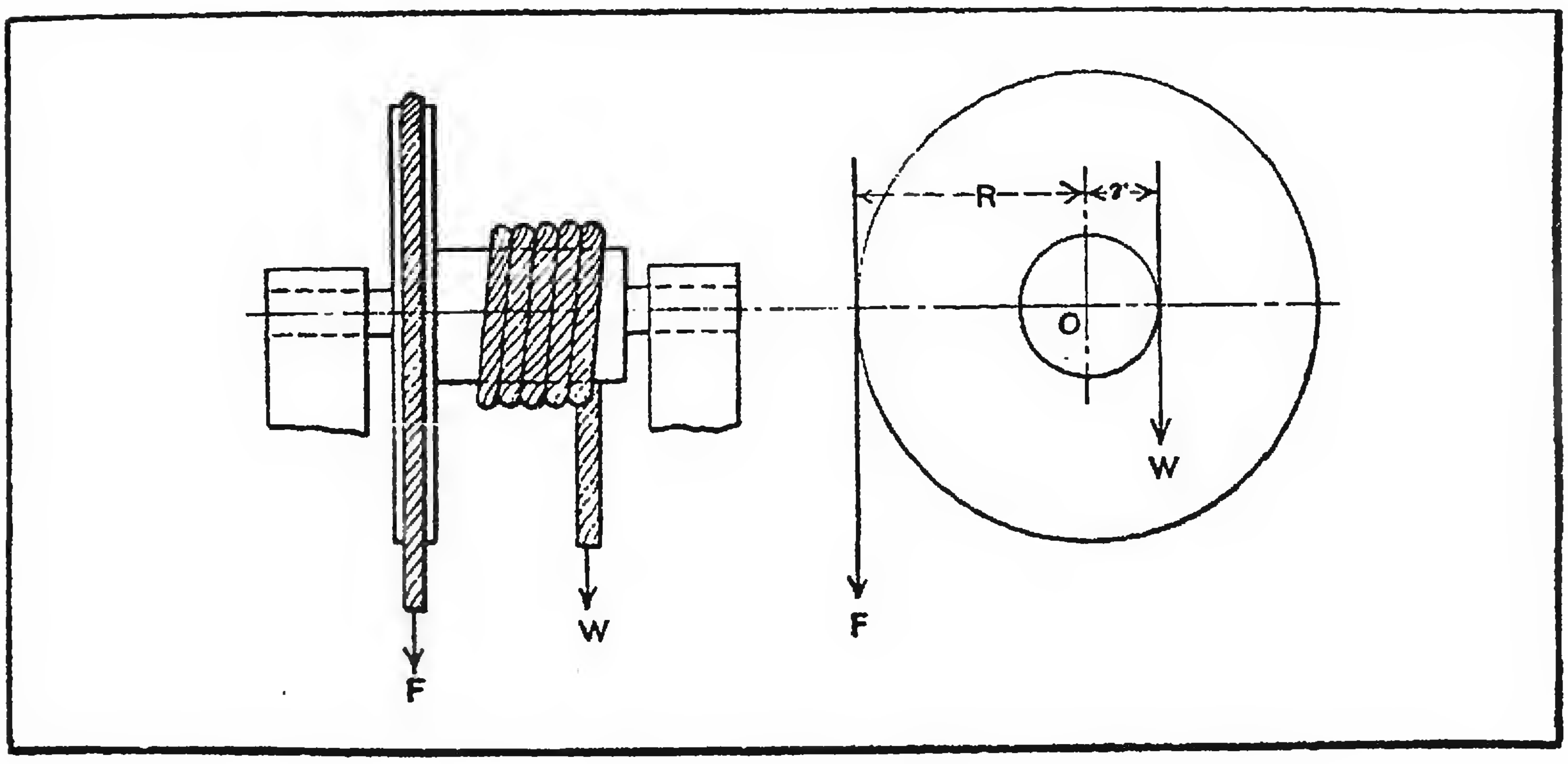
Wheatstone bridges are made in many forms. The three known resistances are made adjustable and are usually made of many spools of special resistance wire. The resistances are usually varied by short-circuiting a greater or smaller number of these spools.

Wheel and Axle. One of the so-called "mechanical powers" is known as the wheel and axle. It consists in its simplest form of a grooved wheel, into which fits a cord, rope, or chain, and to which is rigidly attached a shaft or axle, from which a weight is suspended by means of another rope or chain (see diagram). When sufficient pull is applied at F to overcome the resistance of the load attached at W, the weight will be raised. The principle involved is one of lever arms; the lever arm of force F is so much

greater than that of weight W that the force F required to raise the weight can be proportionately smaller.

Let R = radius of wheel at periphery of which force F acts, and r = radius of drum or axle at periphery of which weight W is applied. Then:

$$F : W = r : R.$$
$$F \times R = W \times r.$$



Wheel and Axle

Wheel Chuck. Name applied to a work-holding chuck for machine tools, having a series of annular recesses or steps of various diameters for holding work which must be located very accurately with reference to its periphery. These chucks are generally used in bench lathes for work of larger diameter than could be held in a collet chuck.

Wheel-Turning Lathes. A "wheel lathe" is a special design used for turning locomotive driving wheels and car wheels after they have been pressed onto the axle. Lathes of this class are of duplex form, there being two driving heads and two tool-rests, so that both wheels may be turned simultaneously. One of the spindle driving heads is adjustable along the bed to allow for the variation in the length of axles having inside and outside journals. The toolposts are mounted on compound slides, so that the tools may be fed laterally or longitudinally. The large faceplates of these lathes are usually equipped with special driving dogs of powerful design, so that deep cuts may be taken and coarse feeds used. In some shops, wheels are turned by broad forming tools which are fed straight in without any lateral feeding movement.

White Cast Iron. White cast iron is a cast iron in which the carbon is present in the form of cementite or combined carbon,

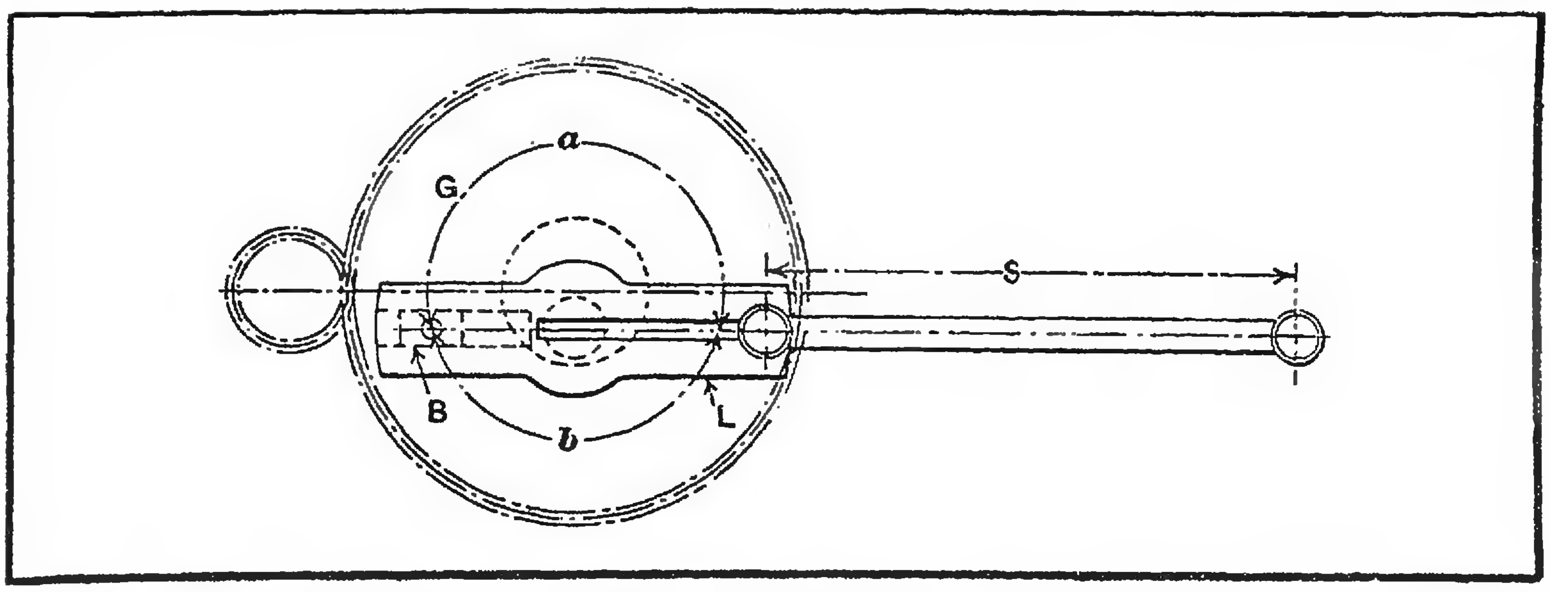
cementite being a carbide of iron, the chemical formula of which is Fe_3C. Carbon in chemical combination directly affects the properties of cast iron. White cast iron is hard, strong, and sound, but cannot be machined easily like gray cast iron.

White Copper. Same as Chinese copper. See Chinese Alloys.

White Lead. Basic carbonate white lead is made in several ways. The old Dutch process consists in placing lead plates or grids in clay pots with dilute acetic acid, stacking the pots up, and covering with tanbark. Fermentation of the latter causes a rise in temperature and the production of carbon dioxide, which acts on the lead in the pots and gives a basic lead carbonate. At the end of two months, the white lead is ground in water, and dried, being ground later in oil. The "quick process" requires but two weeks, and is carried out by the action of dilute acetic acid and carbon dioxide on finely divided lead, in revolving cylinders. In the "mild process" no acid is used, the finely divided lead being agitated in water through which air is blown. Hydrate of lead is formed, and later carbonated. A very good product, free from all acid, is thus obtained. The result of all of these methods is a very valuable pigment with a specific gravity of 6.8, grinding in 9 per cent of oil. It is very opaque and has much body, but is rather low in spreading power and is generally mixed with zinc oxide or pigments of similar nature. Sulphurous gases blacken it easily, and it has a great tendency to chalk, due to the fact that it is naturally alkaline and thus acts on the linseed oil in the paint. It is generally inhibitive in its action and is widely used.

White Metal. The term "white metal" is applied to a number of alloys containing mainly zinc and tin, or lead, tin, and zinc. White metals are used for bearings on railroad cars, generators, motors, etc. The composition of one of these white metals used as a bearing metal is as follows: Lead, 33 per cent; tin, 54 per cent; antimony, 10.6 per cent; and copper, 2.4 per cent. White metal made according to the specifications of the United States Navy Department consists of 88.8 per cent of Banca tin; 3.7 per cent of best refined copper; and 7.5 per cent of regulus of antimony, well fluxed with borax and resin in mixing. Several English railways use from 73 to 77 per cent of tin; from 15 to 19 per cent of antimony; and from 7 to 9 per cent of copper. White metal is sometimes used as a pattern material, especially when it is necessary to avoid shrinkage. The addition of antimony makes the metal almost entirely free from shrinkage upon cooling.

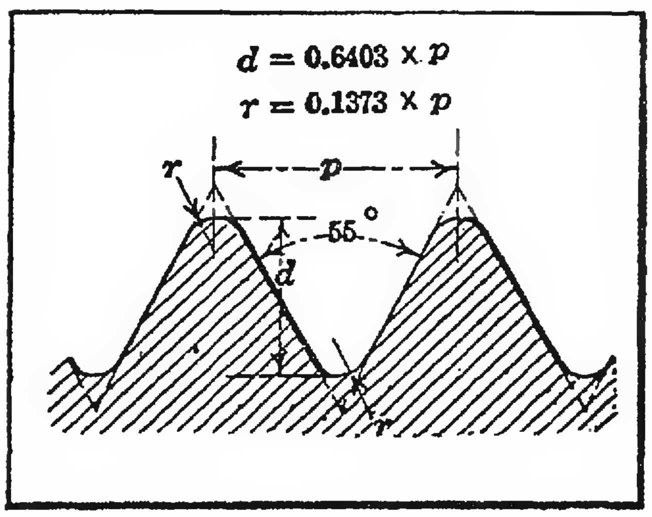
White Nickel Brass. See Brass Alloys for Castings.



Principle of Whitworth Quick-return Motion

Whiting. Calcium carbonate, or whiting, found extensively as chalk, is used to a considerable extent in paints partly because of its power of neutralizing any free acid in the linseed oil. See Calcium Carbonate.

Whitworth Motion. A quick-return method that has been widely used in slotter construction, and on certain classes of shapers and other tools is illustrated by the diagram. This mechanism is known as the "Whitworth motion." The gear *G* drives a slotted link *L*, which is pivoted at the same point within the path of the crankpin or Block *B*, thus permitting the link to rotate through a complete revolution. As the center about which link *L* rotates is offset with relation to the center of the driving gear *G*, the driving pin *B* moves through an arc *a* during the cutting stroke, and through a shorter arc *b* for the return stroke, which, therefore, requires less time, in proportion to the respective lengths of arc *a* and *b*. This mechanism, when incorporated in the driving mechanism of a machine like a slotter, serves to return the ram and tool quickly after the cutting stroke, thus reducing the time for the idle or non-cutting period.



Whitworth Thread

Whitworth Standard Thread. The Whitworth Standard thread, also known as British Standard Whitworth (B.S.W.), is used principally in Great Britain, but also to some extent in the United States. In the Whitworth Standard, the sides of the thread form an angle of 55 degrees with one another. The top and the bottom of the thread are rounded. The radii for these rounded portions are determined by the depth of the thread, which is two-thirds of the depth of a thread of the

same angle, sharp at the top and bottom. The radii at the top and at the bottom are the same. If p = pitch of thread, d = depth of thread, and r = radius at top and bottom of thread, then:

$$d = \frac{2}{3} \times \frac{p}{2} \times \cot 27 \text{ deg. } 30 \text{ min.} = 0.640327\, p = \frac{0.640327}{\text{No. Th'ds per inch}}$$

$$r = 0.137329\, p = \frac{0.137329}{\text{number of threads per inch}}.$$

As the Whitworth thread is rounded at the root and crest, there are no sharp edges or corners from which fractures may start. Screws and nuts having this form of thread will also work well together after continued heavy service. In the United States, Whitworth threads have been used on special screws and on a great many staybolts for the fire-boxes of locomotive boilers. A series of tests have indicated that the Whitworth thread is somewhat stronger than the American Standard form.

Whitworth Thread Origin. The work of the earlier generation of English tool builders culminated in that of Sir Joseph Whitworth. He, like most other English mechanics, was a North-country man, who had worked for both Maudslay and Clement. The succession of influence running through these men is singularly illustrated in the development of standard screw threads. Maudslay standardized the screw-thread practice of his own shop, settling upon and adhering to a definite number and size of threads for each size of screw then in use. Clement, who worked for Maudslay, adopted these standards, improved them, began the manufacture of taps and dies, and invented the tap having a small shank to enable it to fall through the tapped hole, thereby avoiding the necessity for backing out the tap. Whitworth took up the work of Clement and Maudslay, and, after making a careful study of all the threads in general use, proposed, in a paper before the Institute of Civil Engineers in 1841, the standard which became general throughout Great Britain and continues today as the Whitworth Standard thread. Most of the general tools had been invented by the time Whitworth began his independent work, but he so improved their design and workmanship that he influenced English tool practice for several generations. He introduced an accuracy in commercial work unknown until that time, which was made possible by his improvements in the methods of measurement.

Williams Internal Gear. See Internal Gear, Williams.

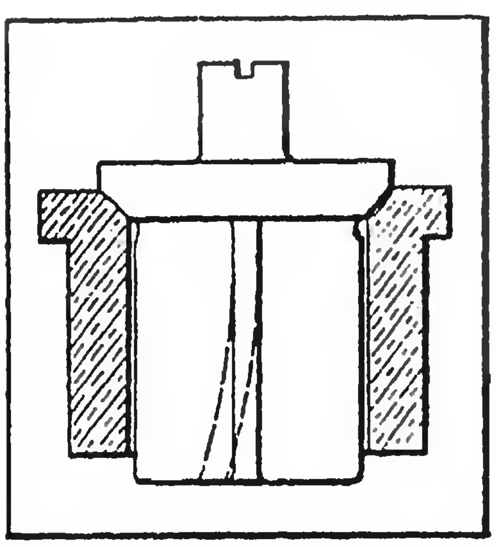
Willow Charcoal. Willow charcoal, used in the making of

paints, is made by charring certain kinds of wood, and contains a slight amount of alkali, which is probably the cause of its good inhibitive powers. It is a light pigment, and grinds to a paste in 33 per cent of oil.

Winchester Bushel. A measure of capacity or volume, legal in the United States, and equal to 2150.42 cubic inches. This measure has not been legal in Great Britain since 1825, when it was superseded by the Imperial bushel which is equal to 2218.19 cubic inches.

Wind Pressures. Wind pressures per square foot for different wind velocities in miles per hour are as follows: Fresh breeze of 10 miles per hour, pressure 0.4 pound; stiff breeze of 20 miles per hour, pressure 1.6 pounds; strong wind of 30 miles per hour, pressure 3.6 pounds; high wind of 40 miles per hour, pressure 6.4 pounds; storm with velocity of 50 miles per hour, pressure 10 pounds; violent storm with velocity of 60 miles per hour, pressure 14.4 pounds; hurricane with velocity of 80 miles per hour, pressure 25.6 pounds; violent hurricane with velocity of 100 miles per hour, pressure 40 pounds per square foot. The foregoing figures are based on data obtained by the U. S. Signal Service at Mt. Washington, N. H.

Wing Valves. A wing valve is so called because it is guided in its vertical movement by wings which extend down below the valve-seat. The wings of some valves are curved slightly (as shown by the dotted lines of the accompanying sketch) so that the valve will automatically rotate part of a revolution each time the liquid is forced through it. The object of designing the valve to secure this turning movement is to wear both the valve and seat more evenly. In order to avoid obstructing the valve port, some valves are guided by a stem which enters a bonnet above the valve. With such an arrangement, the stem should be fluted or other provision made to prevent the formation of a partial vacuum above the valve stem, as this would delay the return of the valve to its seat.



Wing Valve

Wiped Joint. A joint, usually of two heavy electrical cables, made by pouring molten lead at the juncture and wiping it all around with cloth pads until it hardens and forms a neat encasement of the juncture. Temperature control is very important.

Wire Classification. Wire is classed according to the size and shape of its cross-section as: Coarse round wire, fine round wire, and shaped wire.

Coarse Wire: Coarse round wire is drawn on blocks larger than 8 inches in diameter, in sizes 20 gage or coarser. Coarse wire is naturally limited in bending, therefore large-diameter blocks are used.

Fine Wire: Fine round wire is drawn on 8 - inch diameter blocks in sizes 16 gage or finer. When fine wire is drawn on large-diameter blocks, there is a tendency for the coils to twist into the form of a figure 8. In certain gages of wire, the choice of block size is determined by manufacturing conditions.

Shaped Wire: Shaped wire is any wire not round in section; it may be square, rectangular, hexagonal, triangular, half-round, oval, etc. Some sections of shaped wire may be either rolled or drawn. Shaped wire is a specialty, subject to agreement between purchaser and manufacturer as to size, finish, temper, and weight of coils and packages. See also Wire Grades.

Wire Drawing. Wire drawing is the process used for producing wire by drawing a wire or rod of larger diameter through a plate or die provided with a hole which reduces the size to the desired dimension. Briefly described, the machines used for wire drawing consist of a die or "draw-plate" provided with a hole through which the wire is drawn, and means for pulling the wire through these dies and winding it upon a reel.

The "wire rod" from which wire is drawn is a semi-finished hot-rolled product approximately round in cross-section. To start the drawing, one end of the rod is pointed, inserted through the die and attached to a power-driven cylindrical block, which pulls the rod through the die and coils the resultant wire.

Scale Removal: Before drawing, the scale is removed from the rod by acid pickling. The rod is then washed in clear water, dipped in a vat containing hydrated lime in suspension and baked to dry the lime coating and to liberate hydrogen which may have been absorbed by the steel in the pickling operation. For certain types of wire the cleaned rod may be sprayed with water for a time sufficient to produce on the rod surface a coating of ferrous hydroxide, or sull. This deposit of ferrous hydroxide, with the subsequent lime coating, is baked onto the surface of the rod.

The Drawing Die: The die originally was a chilled cast iron die, or a punched, heat treated steel plate. Within recent years, these older die forms have been superseded by carbide dies, which are extremely hard and wear resistant. A carbide die consists of a nib encased in an annular supporting ring of steel. The nib consists of one or more carbides (tungsten, tantalum, titanium, etc.)

mixed with a bonding agent, such as cobalt, pressed into the desired shape and heat-treated or sintered into its hardened rough form, after which it is mounted, sized and polished.

Drawing Lubricants: In the drawing operation, various materials are employed as lubricants to produce different finishes on the surface of the wire and to minimize die wear. In dry drawing, the base for lubrication is the lime (or sull and lime) baked on the surface of the cleaned rods, supplemented by soap or grease in the die box or die container. Wet drawing is employed in the manufacture of some classes of fine wire, for the light drafting of coarse wire, and for the purpose of producing special finishes. In wet drawing, the rods are usually dry drawn to first suitable size preparatory to the wet drawing procedure. The wire, with or without a heat-treatment, is then cleaned and immersed in a solution which provides a light coating of copper or tin, or a combination of copper and tin, depending upon the finish desired. The wire thus prepared is drawn wet, from or through a liquid lubricating solution.

In single draft drawing, the wire is drawn through one die at a time, the wire being removed from the block and redrawn through the next smaller die, until the desired size is reached. In continuous wire drawing, the wire is drawn continuously through a series of dies with power-driven blocks between dies. The speed increases on each successive block until the wire is coiled on the last block as in single draft drawing.

Wire Drawing History. Previous to the development of wire drawing, wire was made by hammering or beating metal into thin sheets or plates, which were cut into continuous strips. These strips were then afterwards rounded by hammering. There is evidence that wire was produced by a simple hammering process as early as 2000 B.C., and perhaps earlier. The history of the art does not clearly indicate when simple hammering was superseded by the method of drawing through a die, but records are available to show that wire drawing on a commercial scale was practiced in France in 1270, in Germany in 1350 and in England in 1465. The first wire-drawing mill in America was built in 1775, in Norwich, Conn., by Nathaniel Niles, who was granted a loan of $1500 by the court for this purpose.

Wire Feed. The name "wire feed" is often applied to the mechanism for feeding a rod through the spindle of a screw machine. The term "wire-feed screw machine" is sometimes used to indicate a design having a mechanism for automatically feeding the stock through the spindle, whereas a machine not having this stock-feeding mechanism may be designated as a *plain screw* machine.

Wire Forming. Nearly every conceivable shape can be produced in wire by the use of a wire-forming machine, supplemented in some instances, particularly where ribbon stock is to be formed, by the power press. The various machines in common use are designed to operate practically in the same manner. They consist fundamentally of four cam-operated slides arranged 90 degrees apart; these advance to a common center at which point a vertical member, called the "king-post," is located. The king-post is the member around which the wire is shaped by the dies or forming members that are carried in the slides. Obviously, the range of service of the machine depends upon the ingenuity employed in laying out suitable cams and in setting up the job. Considerable variation from the four-slide arrangement is practicable, because it is possible to mount auxiliary cams on each camshaft for operating levers and additional slides, so that pieces requiring more than four bending operataions can be produced by thus increasing the scope of the machine.

The forming dies are simple in construction, and consist of finger members attached to the slides, usually provided with a groove at the end to receive and guide the wire as it is bent. Auxiliary levers are frequently interposed between the slides when extra bending members are required, and these are essentially of the same design as the dies except that they usually move independently of the slides. The movements necessary to form a piece of wire into a more or less complicated shape may be varied in their sequence. The first consideration when a part is to be manufactured is the proper starting place in relation to subsequent operations. It has been found, even after large quantities of pieces have been manufactured commercially by one method, that greater production can be obtained by making certain simple changes which affect the entire cycle of the movements and completely revise the manufacturing procedure.

Wire Gages. See Gages for Wire.

Wire Grades and Finishes. The following information applies to coarse round wire, with the exception of the final paragraph on Fine Round Wire.

Bright Wire is hard dry-drawn wire, produced without any treatment or processing designed to alter the properties imparted by cold drawing. The use of bright wire is therefore confined to applications not requiring special finishes, specific tempers or hardness involving modifications of the normal wire-drawing procedure.

Bright Soft Wire, sometimes called annealed-in-process wire or processed wire, is dry-drawn wire, annealed at a point intermediate between the rod size and the finished size in order to produce

a softer wire for applications in which bright wire would be too hard or too stiff.

Extra Clean Smooth Bright Wire is dry-drawn wire produced by varying the lubrication and drafting in order to obtain an especially clean, smooth, bright surface. This finish is obtainable in all grades of dry-drawn wire and is intended for use where clean, smooth surface is of prime importance to some subsequent operation such as spot-welding, electroplataing, tinning, enameling or similar processes. Special wire drawing practice, requiring extra drafting is necessary to produce this finish.

Sull Coated Wire is drawn from rods or wire which, after acid cleaning, have been subjected to fine sprays of water in order to produce a uniform sull coat, the purpose of which is to form, with the subsequent lime coating, a base for the drawing lubricant.

Merchant Wire is general-purpose wire furnished in annealed or galvanized finishes. It is generally sold by retail stores, for the purpose of bracing, tying, and similar uses. It is furnished in even weight bundles, the standard weight of which is 100 pounds. It is also supplied in special bundle weights of 5, 10, 25 or 50 pounds. Bundles consist of from one to three pieces.

Market Wire is a general-purpose merchant wire supplied in bright annealed, galvanized, tinned, and coppered finishes. This is a low carbon steel wire, annealed-in-process, so as to be medium soft to take various forming operations. It is supplied in standard 100 pound coils of one piece. It is sold by hardware stores and other retailers.

Stone Wire is a general-purpose annealed or soft-galvanized wire for common uses, such as stove-pipe wire, hay-stack wire, tying wire, and other general home and farm utility purposes. It is packed in 8-inch diameter paper wrapped bundles of 12 pounds each which may contain from one to three pieces.

Cold Heading Wire is produced by specially controlled manufacturing practices and is subjected to mill tests and inspections designed to assure internal soundness, uniformity of chemical composition and freedom from injurious surface defects, thus providing satisfactory cold-heading and cold-forging performance and proper response to subsequent heat treatment under standard manufacturing conditions.

Welding Wire is suitable for use in gas or electric-arc welding. The wire is manufactured to give satisfactory performance under the action of the gas flame or the electric arc. These requirements involve extra precautions in the manufacture of the steel, in the selection and preparation of the billets, and in making tests of the rods and wire.

Spring Wire is suitable for use in the manufacture of springs, such as upholstery, bed, automobile seat and cushion springs. The

wire is drawn from rods of specially prepared steel, properly patented, and is subjected to mill tests and inspection designed to give assurance that the extra precautions taken in its manufacture have produced the quality suitable for the purpose.

Telephone and Telegraph Wire is made by practices and of chemical compositions designed to produce electrical and physical properties that will meet the requirements of the respective standard grades. *EBB* stands for "Extra Best Best" and signifies steel wire of lowest electrical resistance; *BB* stands for "Best Best" and signifies steel wire of medium electrical resistance. *Steel* signifies wire which may be of maximum resistance permissible in communication lines.

Annealed Wire is wire which has been softened at its finished size by heating to relieve the hardening effects of cold drawing.

Patented Wire is drawn from hot-rolled rods or wire, which have been given a preparatory strand heat treatment by heating to a temperature above the critical range, followed by comparatively rapid cooling. Wire with a carbon content higher than 0.40 per cent is drawn from patented stock in order to make the material tough enough to withstand severe distortion or drafting without actual or incipient breakage.

Oil Tempered Wire is a high-carbon wire which has been heat treated at finished size, by heating to a temperature above the critical range, quenching in oil, and then passing through a bath maintained at the temperature required to produce the temper desired in the finished wire.

Coppered Wire and Liquor Finished Wire are produced by wet drawing wire which has been immersed in a copper sulphate or copper-tin sulphate solution. The solution used is dependent upon whether copper finish, brass finish or white finish is desired. The temper of the finished wire is controlled by processing prior to wet drawing.

Tinned Wire is given a coating of tin by passing single strands through a bath of molten tin. The temper of the finished wire is controlled by processing prior to the tinning operation.

Galvanized Wire is given a coating of zinc by passing single strands through a bath of molten zinc, or through an electrolytic cell containing a solution of zinc salt. This wire is usually annealed before coating.

Fine Round Wire: By *fine wire* is meant wire in gages 16 (0.062 inch) or finer, drawn on 8-inch diameter blocks. There is a range from 16 to 20 gage in which the distinctions are not clearly drawn, as certain kinds of wire may be regarded as coarse wire, while the same size for other purposes and with different manufacturing processes may be regarded as fine wire. There are few standard grades in fine wire. Because of the variety of uses it is impos-

sible to set exact specifications for all applications. Wire for the same use must be made harder or stiffer for some users than for others, and therefore, except in a very few cases, the purchaser's individual requirements are the controlling factor when establishing a wire drawing practice. For this reason it is not practicable to furnish a detailed list of practices by which fine wire may be made. Fine wire may be furnished in the usual finishes available for coarse wire.

Wireless Telegraph. The development of wireless telegraphy was due to the work of several men, including Heinrich Hertz, a German scientist; Tesla in the United States; Branly and Ducretet of France; Popoff of Russia; Prof. Lodge of England; and Righi and Marconi of Italy. In 1899 Marconi, as the result of his developments, succeeded in communicating between points in England and France for a distance of 32 miles across the English Channel.

Wire, Plow Steel. See Plow Steel Wire.

Wire Rods. Wire rods are hot rolled from billets to an approximate round, and receive no additional processing to obtain a more accurate cross section or to improve the surface. They are rolled to specified dimensions and are produced in coils of one continuous length, wound counter-clockwise. Wire rods are classed as a semi-finished product and are intended primarily for the manufacture of wire. They are not comparable to the finished product bars in accuracy of cross section nor surface finished because of the difference in type of mill on which each is rolled.

This product is classed as *carbon steel* when no minimum content is specified or guaranteed for aluminum, chromium, columbium, molybdenum, nickel, titanium, tungsten or vanadium; when the minimum for copper does not exceed 0.40 per cent; and when the maximum content specified or guaranteed for any of the following elements does not exceed the figures given: Manganese. 1.65 per cent; Silicon, 0.60 per cent; Copper, 0.60 per cent.

Size Classification: Wire rod sizes are designated by fractional or decimal parts of an inch or by the gage numbers of the Steel Wire Gage (Washburn and Moen). The smallest size hot-rolled wire rod made is known as No. 5 gage, but custom in the industry has set the minimum nominal diameter of No. 5 gage rods at 0.218 inch. The largest size of wire rods has a nominal diameter of 47/64 inch. Wire rods from No. 5 gage to 15/32 inch, inclusive, are ordinarily produced on rod mills generally by the double or multiple strand method. Wire rods over 15/32 inch to 47/64 inch, inclusive, are commonly produced by the single strand method and are often referred to as combination rods. Aside from the differ-

ences in methods of rolling indicated above, the manufacture of the larger sizes of rods involves additional precautions in steel-making, and the preparation of billets to assure quality equivalent to that more readily obtained in the smaller sizes of rods.

Rods for Merchant Wire Products are suitable for drawing into wire which will be subjected only to simple forming operations as in the case of wire fencing, staples, barb-wire, nails, bale ties, etc. These are run-of-mill rods free from defects injurious to merchant wire products.

Rods for Special Surface Quality Wire are suitable for drawing into manufacturers wire having special surface requirements. These rods are free from defects such as injurious seams, fins, laps, slivers, etc., and are subjected to mill tests and inspection designed to assure that the special precautions taken in their manufacture have produced rods of suitable quality.

Rods for Welding Wire are suitable for drawing into wire to be used for gas or electric arc welding. The rods are manufactured to give satisfactory performance of the wire under the action of the gas flame or the electric arc. Those requirements involve extra precautions in the manufacture of the steel, in the selection and preparation of the billets, and in making tests of the rods.

Rods for Spring Wire are suitable for drawing into wire to be used in the manufacture of springs, such as upholstery, bed, automobile seat and cushion springs. The rods are rolled from specially prepared steel.

Rods for Telephone and Telegraph Wire are made by practices and of chemical compositions suited to the manufacture of wire having electrical and physical properties that will meet the requirements of the respective standard grades. *EBB* stands for "Extra Best Best" and signifies steel wire of lowest electrical resistance; *BB* stands for "Best Best" and signifies steel wire of medium electrical resistance. *Steel* signifies steel wire of maximum resistance permissible in communication lines.

Wire Rope. Wire ropes are made by twisting a number of wires together into a strand, and then twisting a number of strands about a hemp core to form a wire rope. Sometimes the hemp center is replaced by a wire strand which adds from 7 to 10 per cent to the strength of the rope. The strand is usually made by placing one wire in the center and surrounding this with a layer of 6 wires, thus forming a 7-wire strand. If another layer of wires is placed outside of this layer, this new layer will contain 12 wires, and the strand will be a 19-wire strand. An additional layer will contain 18 wires, thus making a 37-wire strand. By adding another layer, this time of 24 wires, a 61-wire strand is obtained; and, in exceptional cases, still another layer

may be added, this time of 30 wires, making a 91-wire strand.

The advantages of wire rope as compared with hemp rope are as follows: Greater strength for the same diameter; greater strength for the same weight; lower cost for the same strength; equal strength whether wet or dry (a hemp rope may lose as much as 30 per cent of its strength when wet); equal length under all weather conditions; greater indestructibility; and greater variety in types of construction that may be applied to different uses. As another advantage may also be mentioned the greater certainty with which the strength of wire ropes may be computed.

Types of Wire Rope: When all the wires used in making a strand are of the same size, the construction is known as a *one-size-wire* type. Another construction, known as the *Warrington* type, or *three-size-wire* construction, makes use of 7 wires of uniform diameter surrounded by a layer of 12 wires of which 6 are large and alternate with 6 smaller wires. The Warrington construction increases the metallic area and, hence, the strength for a given outside diameter of rope by approximately 10 per cent, and is advantageous for general hoisting purposes. Still a third type of construction, known as the *Seale* type, is used. In this, the center wire is large; then there is a layer of 9 small wires, and then an outer layer of 9 large wires. Strands made in this manner will produce a rope which is somewhat stiffer than the ropes made by one-size-wire or three-size-wire construction.

Wire ropes are made from a number of different materials varying from iron wire to the highest grade of special steels. Iron was used almost entirely for wire ropes in the early days of wire rope manufacture. At the present time, it is employed only to a limited extent. Compared with newer materials, it is of a low tensile strength and soft, and although ductile and pliable, it is heaviest in proportion to its strength.

Crucible-steel Wire Rope: Crucible steel is a tough and pliable material of moderate cost when used for wire ropes. It has about double the strength of iron for the same weight; it is also harder than iron, and, therefore, resists external wear better. The steel has derived its name from the early method of making high carbon steel in small crucibles, but the same grade of steel for wire rope is now made by the Siemens-Martin open-hearth process. When drawn into wire, steel of this quality will have an ultimate strength of from 150,000 to 250,000 pounds per square inch, the higher figure applying to the finer wires and the lower to those of larger diameter.

Plow-steel Wire Rope: The name "plow" steel originated in England and was applied to a strong grade of steel wire used in the construction of very strong ropes employed in the mechanical operation of plows. The name "plow" steel, however, has become

a commercial trade name, and, applied to wire, simply means a high-grade open-hearth steel of a tensile strength in wire of from 200,000 to 260,000 pounds per square inch of sectional area. A strength of 200,000 pounds per square inch is obtained in wire about 0.200 inch in diameter. Plow steel when used for wire ropes has the advantage of combining lightness and great strength. It is a tough material, but not as pliable as crucible steel. The very highest grade of steel wire used for wire rope is made from special steels ranging in tensile strength in wire from 220,000 to 280,000 pounds per square inch of sectional area. This steel is especially useful when great strength, lightness, and abrasive resisting qualities are required.

Galvanized Wire Rope: The following information on materials used for wire rope and the practical applications of different materials is from the United States Government specifications: Galvanized wire rope should be used if the rope is likely to corrode because of the presence of moisture, as for the standing rigging of a ship. Because the zinc coating is rapidly removed by wear, it should not, in general, be used for hoisting. It may, however, be used for the running rigging and for wheel (steering) ropes on ships, as these ropes do not wear rapidly.

Uncoated Wire Rope: Uncoated wire rope should be used where it is protected from moisture, as in a building, and for more or less continuous hoisting. It may be used instead of galvanized wire rope where it is exposed to moisture, as for derrick guys, if a protective coating is applied to the rope at regular intervals.

Phosphor-bronze Wire Rope: Phosphor-bronze wire rope has lower strength than steel wire rope; therefore, the working loads should be lower. The sheaves should also be larger than those for steel rope. It is non-magnetic, and can be used for conditions under which galvanized steel rope does not give satisfaction. Because of these properties, it is used on small vessels.

Marline-covered Wire Rope: Marline-covered wire rope is stronger and more durable than manila rope. The marline covering prevents wearing of the wires and supplies lubricant to them. As the marline wears to a smooth surface, the rope is easily handled or laid in a flat coil. Compared with uncovered wire rope, the marline-covered rope is more easily handled, has greater friction, which is an advantage if it is used on a smooth drum, and is more durable, particularly if it is exposed to gases, grit, or moisture.

Wire Rope Definitions. In the following are given brief definitions of commonly used terms met with in the application of wire rope.

Airplane Strand: A small 7- or 19-wire galvanized strand

made from plow steel or crucible steel wire.

Cable Laid Rope: A compound laid rope consisting of several ropes or several layers of strands laid together into one rope, as, for instance, 6 by 6 by 7.

Crane Rope: Wire rope consisting of 6 strands of 37 wires around a hemp center.

Elevator Rope: Wire rope usually made of iron and composed of 6 strands of 19 wires each, and a hemp core.

Extra-flexible Hoisting Rope: A rope consisting of 8 strands of 19 wires each with a large hemp center.

Flat Rope: A rope consisting of alternate right and left lay rope strands, each rope strand consisting of 4 strands of 7 wires, all sewed together with a number of soft iron sewing wires.

Flattened Strand Rope: A wire rope having non-cylindrical strands, usually of the oval or triangular type; the center wire of each strand is an oval or a triangular wire.

Guy Rope: Galvanized rope consisting of 6 strands, 7 wires each, and a hemp core.

Guy Strand: Galvanized 7-wire strand.

Hand Rope: Flexible rope consisting of 6 ropes, each composed of 6 strands, 7 wires each, and 7 hemp cores.

Haulage Rope: Rope usually composed of 6 strands, 7 wires each, and a hemp core.

Hawser: Wire rope usually consisting of 6 strands, 37 wires, and a hemp core, or 6 strands, 24 wires, and 7 hemp cores.

Hoisting Rope: Rope consisting of 6 strands of 19 wires each, with a hemp center.

Lang Lay Rope: Wire rope in which both the wires in the strand and the strands in the rope are twisted in the same direction.

Lay: The pitch or angle of the helix of the wires or strands of a rope, usually expressed by the ratio of the diameter of the strand or rope to the length required for one complete twist.

Left-lay Rope: Wire rope, the strands of which form a left-hand helix like a left-hand screw thread.

Left Twist: Same as right lay, and corresponds to a right-hand screw thread.

Non-spinning Rope: A rope wire consisting of 18 strands of 7 wires each, in two layers; the inner layer consists of 6 strands Lang lay and left lay around a small hemp core, and the outer of 12 strands regular lay, right-hand lay. Will carry a load on a single end without untwisting.

Regular Lay: Strands twisted to the right and rope twisted to the left. Helix of strands takes the direction of a right-hand screw thread.

Reverse Laid Rope: A wire rope with alternate strands right and left lay.

Rheostat Rope: A small rope consisting of 8 strands of 7 wires each.

Right Lay: Known also as regular lay; strands twisted to the right and rope twisted to the left; corresponds to a right-hand screw thread.

Right Twist: Corresponds to left lay, or to a left-hand screw thread.

Running Rope: A flexible rope of 6 strands, 12 wires each, and 7 hemp cores.

Special Flexible Hoisting Rope: A wire rope consisting of 6 strands, of 37 wires each, and a hemp core.

Standing Rope: Another term applied to galvanized guy rope which consists of 6 strands, 7 wires, and a hemp core.

Towing Hawser: A large flexible wire rope made of galvanized wires. Usual construction, 6 strands of 37 wires each, or 6 strands of 24 wires each.

Transmission Rope: Rope composed of 6 strands, 7 wires each, and a hemp core.

Wire Rope Drums. The drums used for wire ropes should be grooved rather than flat. The grooves should be so spaced on the drum that there is ample clearance between the successive windings on the drum. For example, a drum for a 1-inch rope should have the centers of the grooves at least 1 1/16 inches apart. If the groove is made in this manner, the successive convolutions of the rope will not rub against each other. The grooves of all sheaves and drums for wire rope should be smooth, so that they do not cause abrasion to the rope wound upon them. The grooves should also be of a slightly larger radius than the radius of the rope, so that there will be no wedging or pinching action. If possible, the drum upon which a wire rope is wound should be wide enough so that the rope may be wound upon it in one layer. It is bad practice to wind the rope upon the drum several layers deep. The respective layers of the rope will wear against each other and the life of the rope will be considerably shortened. When there is not space enough for a large drum, flat wire ropes, which may be wound in successive layers, are often used.

Wire Rope Lay. See Lay of Wire Rope.

Wire Rope Lubrication. Practically all the cores of good brands of wire rope are thoroughly impregnated with a commercial, chemically neutral rope oil. While the core retains a liberal

supply of this lubricant, frequent application of a good lubricant during service, to prevent the core from becoming dry, is advisable. A dry core will both wear and crush quicker than an oil-impregnated core and it will absorb moisture, with the result that the core will deteriorate rapidly and the inner wires will corrode, thus shortening the rope service. The smaller the sheaves or the heavier the tension on the rope, the more often should the rope be lubricated. A good lubricant retards corrosion of the wires and deterioration of the core, reduces internal friction which is the cause of wires breaking from bending stresses, and decreases external wear. The lubricant should be thin enough to penetrate the strands and the core, but not so thin as to run off the rope, nor so thick that it merely covers the rope. Therefore, semi-plastic compound applied hot (in a thinned condition) is the best wherever possible. It will penetrate while hot, then cool to a plastic filler, excluding the entrance of water, and both preserving and lubricating the inner wires and cores. To lubricate properly with a heated lubricant, it is necessary to have the rope run slowly through a tank of heated oil.

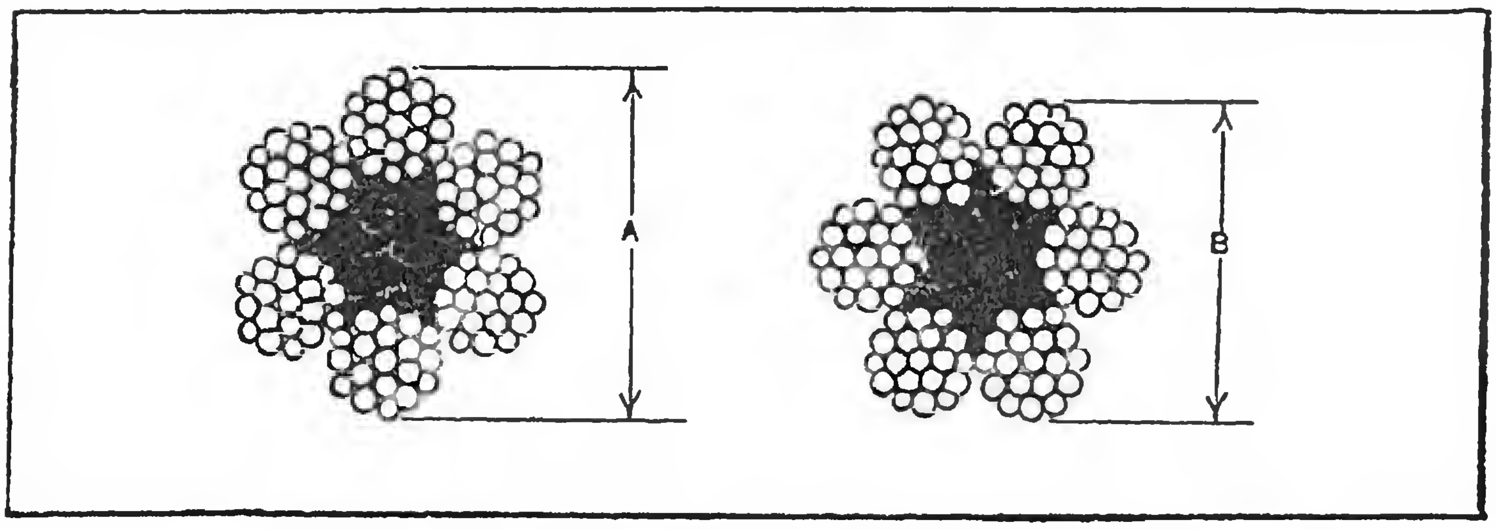
Government Specifications: The following information on the lubrication of wire rope is taken from the United States Government specifications for wire rope: Wear of a running wire rope occurs where the outside wires come into contact with the sheaves and drums, especially if slipping takes place, and, also, where the inner wires of the rope are in contact. During the fabrication of a wire rope, the fiber core is saturated with lubricating compound, which in service is gradually supplied to the wires and reduces the wear on them. As the core will not carry enough lubricant for the life of the rope, it is necessary occasionally to apply a lubricant to the outside of the rope, which will be absorbed by the core. A mixture of a heavy-bodied lubricant and a good grade of graphite is as satisfactory as any of the proprietary lubricants, and is cheaper. A viscous preparation which remains on the outside of the rope does not lubricate the inner wires of the rope.

For elevator cables, any lubricant containing an opaque substance is undesirable, as it interferes with the proper inspection of the rope by making it difficult to detect broken wires. Graphite and similar lubricants may cause excessive sliding of cables on traction-drive elevators, and should not be used on this type of equipment. Boiled linseed oil, applied hot, will saturate the hemp center and will give a transparent covering when dry that will not interfere with the thorough inspection of the rope. If an uncoated wire rope is to be used where it is likely to corrode, the lubricant should have a very heavy body and be applied to the rope so hot that it will penetrate to the core.

Wire Rope Measurement. The correct way to measure wire rope is shown at *A*, in contrast to the incorrect method as at *B*, in the illustration on page 1408. It is important that the proper size of rope be employed, since an under-sized rope will not give the degree of service that should reasonably be expected, while an over-sized rope represents needless investment.

Wire Rope Tests. Experiments made at the Bureau of Standards indicate that a six-strand, nineteen-wire, plow-steel, ⅝-inch wire rope, when bent over a 10-inch sheave, loses 12.6 per cent of the strength that it has when straight, and when bent over an 18-inch sheave, 4.7 per cent. A 1¼-inch rope loses 24.2 per cent, when bent over a 10-inch sheave, and 15.3 per cent on an 18-inch sheave. The wires of which the ropes were composed had a strength of 230,000 pounds per square inch, and the strength of the rope itself, when straight, equaled $83{,}000d^2$, in which d is the diameter of the rope in inches. The modulus of elasticity of steel wire rope may be assumed to be about 8,500,000.

Wire Rope Uncoiling. Wire rope is ordinarily shipped and received either in coils or on reels. In uncoiling or unreeling wire rope, it is essential that no kinks be allowed to form. Once a kink is made, no amount of twisting or strain can take it out, and the rope is unsafe for work. Never uncoil a wire rope as you would a rubber hose or manila hemp rope. Place the coil on its edge and unroll the coil, allowing the rope to lie flat until used.



(A) Correct and (B) Incorrect Methods of Measuring Wire Rope Diameter

Wire Straighteners. Wire straighteners are made in the "double-roll" and the "rotary" types. The double-roll type is made in two forms—with rolls grooved to fit round wire and with wider plain rolls adapted to flat wire or ribbon stock. The double-roll and the rotary type of straightener are each adapted to its particular work and either may be applied, according to the char-

acteristics of the article to be made or the quality of wire to be used.

The double-roll straightener is the one generally used. When used for round wire, one set of rolls is arranged horizontally and another set vertically, the rolls being grooved. For ribbon stock, the rolls are plain and arranged vertically only. The rolls are not located opposite each other but are staggered, and adjustment is provided for bringing them closer together or setting them farther apart to accommodate various thicknesses of stock. The action is very much the same as when drawing a piece of wire through the fingers. The wire is bent slightly in one direction and immediately afterwards in the opposite direction. If released, the wire would take an intermediate position about halfway between the two bends. The adjustment of the rolls is such that this bending back and forth takes out all bends and kinks and the wire leaves the straightener practically or "commercially" straight. A commercially straight wire appears absolutely straight to the average eye, and this is all that is required for most articles. There are articles, however, in which greater refinement is necessary as to straightness, and the double-roll straightener is displaced by the rotary type. The double-roll type is not adapted to the straightening of hard spring wire.

The rotary straightener has a steel spindle containing staggered steel guides. The wire is brought through a quill in the end of the spindle, and it then passes over the steel guides and out through the opposite end. The spindle is made to revolve rapidly and at the same time is reciprocated backward and forward, being mounted in a bracket on a slide and moving with the feed mechanism of the machine. With this type of straightener, wire can be made as nearly straight as it is possible to obtain it. For products such as typewriter bars, where perfect alignment must be had, the rotary straightener must be used to obtain satisfactory results. It is also used for working hard spring wire.

Wiring Dies. See Curling and Wiring Dies.

Wiring Frame. Sometimes it is necessary to mount a curling or wiring die in a horizontal slide attached to the press bed so that it can be drawn out from under the die for the insertion or removal of work. These slides, called *wiring frames,* are operated by hand and are necessary on some presses; otherwise the work could not be inserted or removed from the die when the latter is directly beneath the punch, owing to the limited space. One design of special *wiring press* has a die slide which is automatically operated, thus avoiding hand operation and the resulting fatigue and loss of time.

Wood Boring, Auger Speeds See Auger Speeds.

Wood Creosoting. See Creosoting Process.

Wood, Factor of Safety. The belief that a timber with a so-called "factor of safety" of 3 or 4 will carry three or four times the load for which it is designed is erroneous and has been the cause of failure through the overloading of structures. Only a small part of the usual "factor of safety" for wood is available for taking care of overloading; most of it is required to allow for the known variations in the strength of clear wood, the effect of defects, the moisture conditions of service, and the duration of the load.

Some of the working stresses assigned by the Forest Products Laboratory, Madison, Wis., to structural timbers, when compared with laboratory test data on small, clear specimens, have an apparent "factor of safety" as high as 10, but in reality such factors make allowance for an accidental overload of only 50 per cent. The "factor of safety" for timber is not designed to take care of large overloads. In good construction, occasional timbers might be expected to fail immediately if they were subjected to only twice their design loads. Forty per cent of the timbers would probably fail if such loads were applied for a long time. See also Timbers for Structural Use.

Wood Life. The life of wooden poles for transmission lines varies according to the kind of wood, rapidity of growth, amount of sap at time of cutting, and seasoning after cutting. The following figures, based on a large number of observations, indicate the average life of untreated poles: Cedar, 13 to 14 years; chestnut, 11 to 12 years; cypress, 9 to 10 years; juniper, 8 to 9 years; pine, 6 to 7 years. Poles cut during the winter months when the sap is low always have a longer life than those cut in summer when the sap is up. The proper seasoning of poles also has a great influence on their life. They should be trimmed and peeled immediately after being cut, and should be supported on skids in separate layers for a period of from six months to a year, so that they will be thoroughly air-dried. It is now almost universal practice to give the butts of the poles and sometimes the cross-arms and tops a preservative treatment. Often the entire pole is treated. There are a number of different preservative materials that may be used. The principal of these is dead oil of coal tar or so-called "coal-tar creosote." This is a distillate obtained from coal tar at temperatures ranging from 400 to 750 degrees F. Coal tar itself is a distillate by-product obtained in the manufacture of coal gas and coke at temperatures of from 1500 to 3000 degrees F. Coal tar is of little use as a wood preservative, but the creosotes are of great value.

Wood, Lightest. Balsa, one of the commonest trees in the forests of Costa Rica, is said to be the lightest of all known woods, weighing but 7.3 pounds per cubic foot. Ordinary cork is three times as heavy as Balsa wood. This wood is very soft, and can be readily indented with the finger nail. It absorbs water readily, but it may be treated with paraffin, and then used in making floats for life preservers and in the construction of life rafts. It is also used for buoys and floating attachments to light signals.

Wood, Plastic. See Plastic Wood.

Wood Preserving Process. See Creosoting Processes; also Kyanizing.

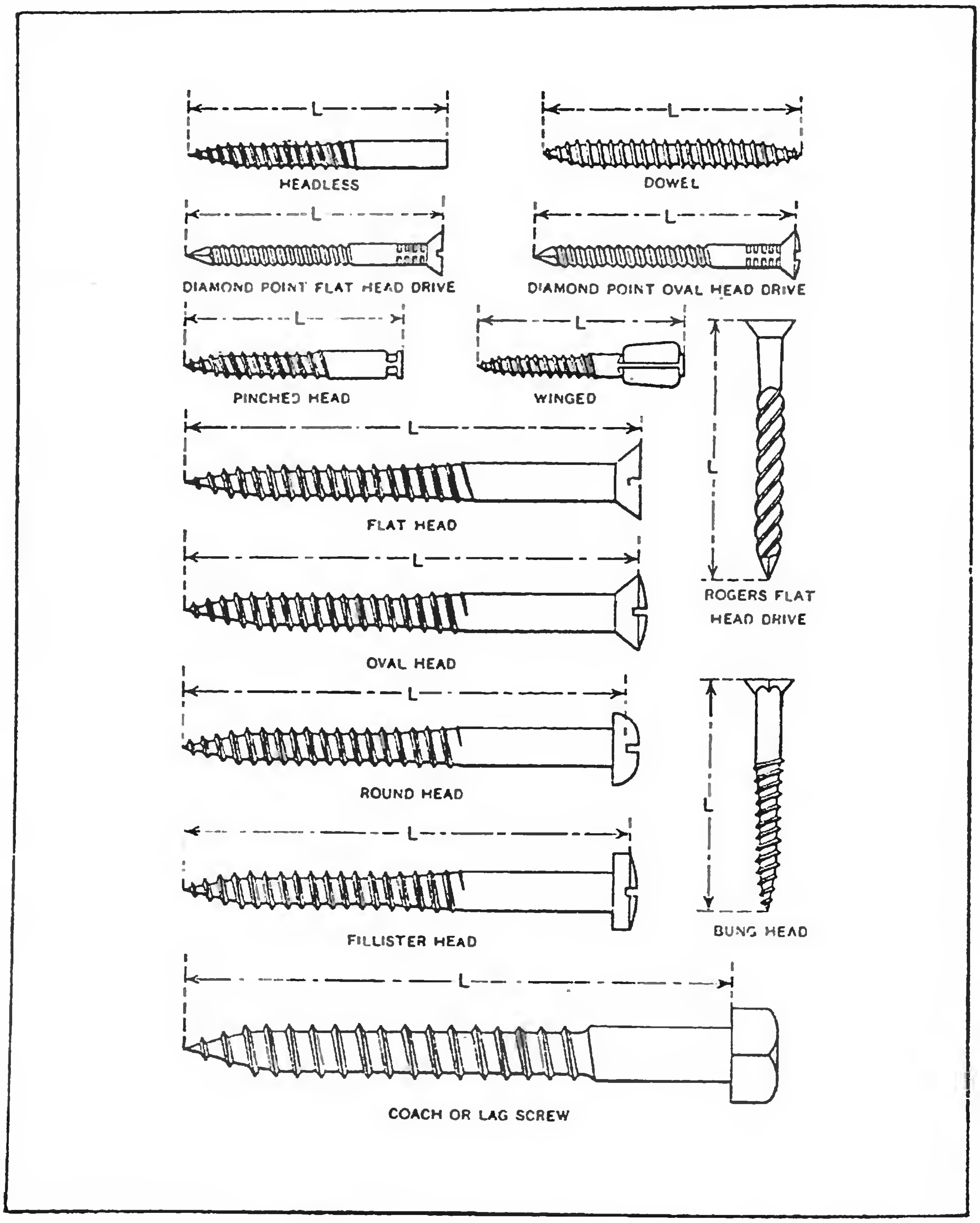
Woodruff Keys. In the Woodruff key system, half-circular disks of steel are used as keys, the half-circular side of the key being inserted into the keyseat. Part of the key projects and enters into a keyway in the part to be keyed to the shaft in the ordinary way. The advantage of this method of keys is that the keyway is easily milled by simply sinking a milling cutter, of the same diameter as the diameter of the stock from which the keys are made, into the shaft. The keys are also very cheaply made, as they are simply cut off from round bar stock and milled apart in the center. Dimensions of Woodruff keys are given in engineering handbooks.

Wood-Screw Holding Power. One-half inch diameter wood-screws, driven 4 inches into wood, have a holding power of about 2500 pounds; ½-inch lag screws, driven 1½ inches into wood, have a holding power of about 1500 pounds, and, if driven 2½ inches into wood, of 2000 pounds. In all these tests the wood was Norway pine. Five-eighth-inch lag screws, driven 4½ inches into seasoned white oak, show a maximum holding power of 8000 pounds; the same screws driven into yellow pine, 4000 pounds

Wood Screws. The American Standard for wood screws includes both the flat-head and round-head forms. The sizes are indicated by numbers and range from No. 0 to 24. The equivalent diameters range from 0.060 inch to 0.372 inch and are the same as the equivalent diameters for machine screws, although wood screw sizes such as Nos. 11, 14, 16, 18, 20 and 24, are not included in American Standard machine screws. Various forms of wood screws are shown in the accompanying illustration. The nominal length of the different forms is indicated by dimensions *L*. According to this illustration, the length of the round-head type is from the bottom of the slot; but the nominal length of an American Standard screw is measured under the head. The range of lengths for each screw number is included in the

American Standard. The number of lengths for each screw size varies. Commonly used sizes, such as No. 6 to No. 18, are made in twelve to fourteen different lengths, whereas small sizes, such as No. 0 to No. 5, are made in two to eight lengths.

Wood Seasoning Processes. There have been differences of opinion as to whether kiln-dried wood is as strong as wood that has been air-dried. In order to determine the relative properties the Forest Products Laboratory of the United States Forest Service at Madison, Wis., made some 150,000 comparative strength tests on specimens from twenty-eight different common



Wood-screws of Different Forms

species of wood. The results of these experiments showed conclusively that good kiln-drying and good air-drying have the same effect upon the strength of wood. The belief that kiln-drying produces stronger wood than air-drying is usually the result of failure to consider differences in moisture content. The moisture content of wood, on leaving the kiln, is usually from 2 to 6 per cent lower than that of thoroughly air-dried stock. Since wood increases in strength with loss of moisture, higher strength values may be obtained from kiln-dried than from air-dried wood; but this difference in strength has no practical significance, since eventually a piece of wood will come to approximately the same moisture condition, whether it is kiln-dried or air-dried.

Wood's Metal. The composition of Wood's metal, which is a so-called "fusible metal," is as follows: 50 parts of bismuth, 25 parts of lead, 12.5 parts of tin and 12.5 parts of cadmium. The melting point of this alloy is from 66 to 71 degrees centigrade (151 to 160 degrees F. approximately).

Wood, Weight Per Cubic Foot. The following weights, in pounds, of various woods grown in the United States, are at the moisture condition of the trees when felled, if the wood is classified as "green." The air-dry weights are for wood at a moisture content of 12 per cent, which is approximately the condition reached without artificial heating by material sheltered from precipitation. In any lot of lumber of a given species in the air-dry condition at 12 per cent moisture, the weight per cubic foot will rarely vary more than 10 per cent from the figures given. In green material, on the other hand, the variation may occasionally be as great as 20 per cent, owing to wide differences in moisture content.

The figures following the name of each wood represent the weight per cubic foot, first, of green wood and then, of air-dry wood having a 12 per cent moisture content. Black ash, green, 52 — air-dry, 34; green ash, 49 — 40; white ash, 48 — 41; aspen, 42 — 27; basswood, 41 — 26; beech, 55 — 44; gray birch, 46 — 35; yellow birch, 58 — 43; Alaska cedar, 35 — 29; western red cedar, 27 — 23; northern white cedar, 28 — 22; southern white cedar, 26 — 23; black cherry, 46 — 35; chestnut, 55 — 30; southern cypress, 51 — 32; American elm, 54 — 35; balsam fir, 45 — 26; Douglas fir, 38 — 34; black gum, 45 — 35; red gum, 50 — 34; eastern hemlock, 49 — 28; western hemlock, 42 — 28; pignut hickory, 64 — 53; shagbark hickory, 64 — 51; western larch, 48 — 36; bigleaf maple, 47 — 34; sugar maple, 56 — 44; black oak, 63 — 43; live oak, 76 — 62; white oak, 62 — 48; jack pine, 50 — 30; longleaf pine, 51 — 41; shortleaf pine, 51 — 38;

western white pine, 35 — 27; western yellow pine, 45 — 28; balsam poplar, 42 — 22; yellow poplar, 38 — 28; redwood, 54 — 30; black spruce, 32 — 28; red spruce, 34 — 28; white spruce, 34 — 27; sycamore, 52 — 35; tamarack, 47 — 37; black walnut, 58 — 39; black willow, 50 — 26; Pacific yew, 54 — 44.

A practical rule for estimating the weight of air-dry or kiln-dry wood at a moisture content of about 12 per cent, is to regard a ½ per cent change in weight as accompanying a 1 per cent change in moisture content. For example, wood at 8 per cent moisture would weigh about 2 per cent less than at 12 per cent, while at 14 per cent the weight would be about 1 per cent more than at 12 per cent.

Work. Work, in mechanics, is the effect of a force acting through a given distance, the force being usually measured in pounds or tons, and the distance in linear units, such as inches, feet, etc. Work is expressed as a product of the units of force (weight) and distance, and is given as inch-pounds, foot-pounds, foot-tons, etc. For example, in lifting a weight of 500 pounds to a height of two feet, 1000 foot-pounds of work has been performed. If one pound is lifted 1000 feet, or 1000 pounds, one foot, the same amount of work has been performed.

Work-Bench Height. See Benches.

Work Diagrams. A "work diagram" is a graphic representation of work done, as, for example, in the cylinder of an engine, air compressor, etc. Work is the result of force acting through space, and the unit of work is the foot-pound, which is the work done in raising 1 pound 1 foot in height. For example, it requires $1 \times 1 = 1$ foot-pound to raise 1 pound 1 foot, or $1 \times 10 = 10$ foot-pounds to raise 1 pound 10 feet, or $10 \times 1 = 10$ foot-pounds to raise 10 pounds 1 foot, or $10 \times 10 = 100$ foot-pounds to raise 10 pounds 10 feet, etc. The product of weight or force acting, times the distance moved, represents work; and if the force is taken in pounds and the distance in feet, the result will be in foot-pounds. This result may be shown graphically by a figure called a *work diagram.*

Let distances on the line *OY* (Fig. 1) represent the force acting, and distances on *OX* represent the space moved through. Suppose the figure to be drawn to such a scale that *OY* is 5 feet in height, and *OX*, 10 feet long. Let each division on *OY* represent 1 pound pressure, and each division on *OX*, 1 foot of space moved through. If a pressure of 5 pounds acts through a distance of 10 feet, then an amount of $5 \times 10 = 50$ foot-pounds of work has been done. Assume, however, that the pressure drops uniformly from 5 pounds at the beginning to no pressure at the

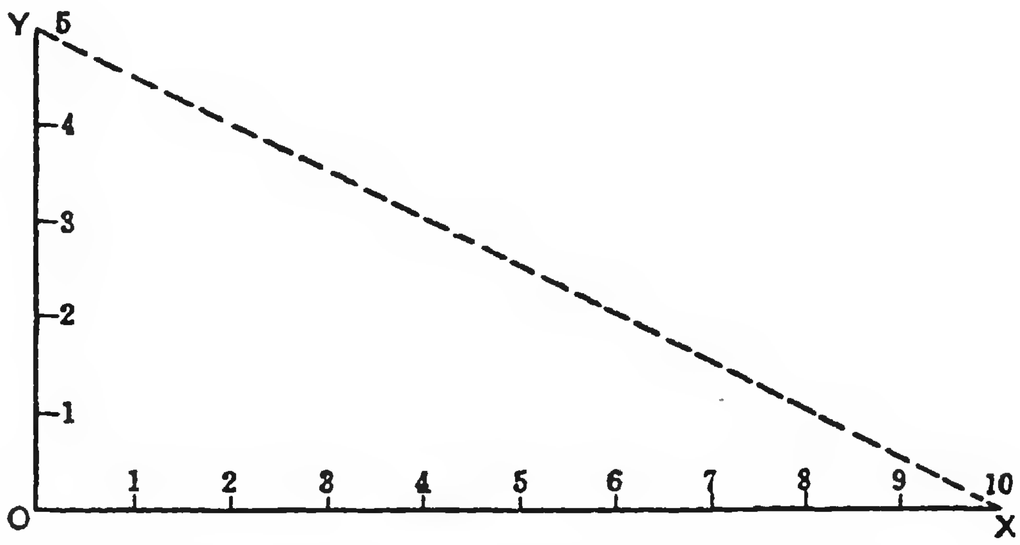


Fig. 1. Work Diagram when Pressure drops Uniformly

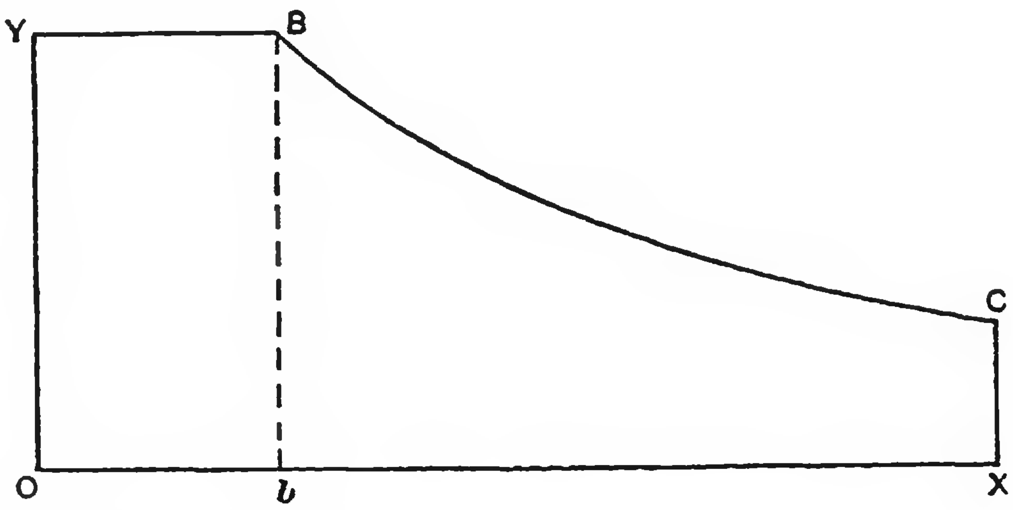


Fig. 2. The Ideal Work Diagram of a Steam Engine

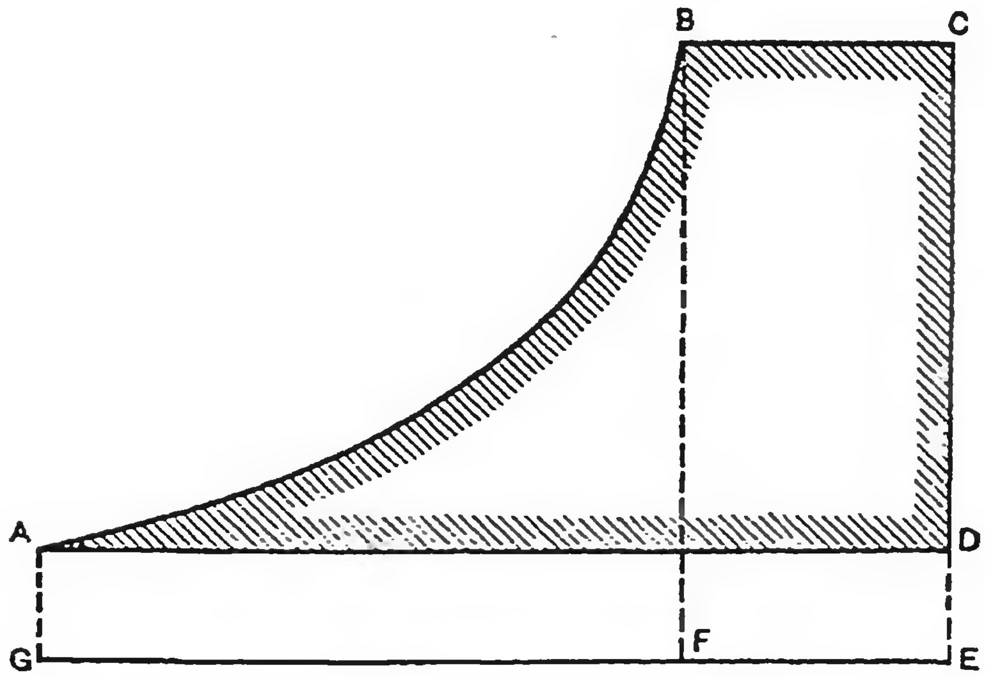


Fig. 3. Work Diagram of Compression

end of the stroke. In this case, the area and work done are found by multiplying the length of the diagram by the average height, as follows:

$$\frac{5+0}{2} \times 10 = 25 \text{ square feet, or 25 foot-pounds of work done.}$$

The object of this illustration is to show how foot-pounds of work may be represented graphically by the areas of diagrams. It is also evident that knowing the area, the average height or pressure may be found by dividing by the length, and vice versa.

The form of work diagram which would be produced by the action of the steam in an engine cylinder, if no heat were lost by conduction and radiation, is represented by the diagram, Fig. 2. Starting with the piston at the beginning of the stroke, steam is admitted at a pressure represented by the height of the line OY. As the piston moves forward, sufficient steam is admitted to maintain the same pressure. At the point B, the valve closes and steam is cut off. The work done up to this time is shown by the rectangle $YBbO$. From the point B to the end of the stroke C, the piston is moved forward by the expansion of the steam, the pressure falling in proportion to the distance moved through, until at the end of the stroke it is represented by the vertical line CX. At the point C, the exhaust valve opens and the pressure drops to 0 (atmospheric pressure in this case).

As it is desirable to find the work done by a complete stroke of the engine, it is necessary to find the average or mean pressure acting throughout the stroke. This can only be done by determining the area of the diagram and dividing by the length of the stroke. This gives what is called the *mean ordinate*, which, multiplied by the scale of the drawing, will give the mean or average pressure. For example, if the area of the diagram is found to be 6 square inches, and its length is 3 inches, the mean ordinate will be $6 \div 3 = 2$ inches. If the diagram is drawn to such a scale that 1 inch on OY represents 10 pounds, then the average or mean pressure will be $2 \times 10 = 20$ pounds, and this multiplied by the actual length of the piston stroke will give the work done in foot-pounds.

Work Diagram of Air Compressor: The action or result of a single stroke of the piston of an air compressor may be shown diagrammatically the same as for steam. The total work done per stroke is represented by the area $GABCE$ (see Fig. 3). At the beginning of the stroke, at A, the pressure is that of the atmosphere, or 14.7 pounds absolute, and is represented by the line GA. During compression from A to B, the pressure increases from GA to FB, the latter being that of the receiver, or the storage chamber to which the compressed air is delivered. The

remainder of the stroke simply forces the air from the cylinder into the receiver at a constant pressure *FB*. It is evident that a single stroke consists of two events, as follows: (1) compressing the air from atmospheric to receiver pressure, and (2) forcing it into the receiver at this pressure. The total work per stroke and that of each event are shown, the total work being represented by the diagram *GABCE;* that of compression, by *GABF;* and that of the discharge, by *FBCE*. The *net* work, or that actually performed by the compressor, and which must be supplied from an outside source, is shown by the shaded portion *ABCD*. The work of filling the cylinder with air, represented by *GADE*, is done by the pressure of the atmosphere and requires no work on the part of the compressor; therefore, this may be deducted from the total work.

Effect of Compression on Temperature: In the foregoing, only pressure and volume have been considered, but in the actual compression of air the temperature is also an important factor. Heat has a tendency to increase either the volume or pressure of air, depending upon the conditions. For example, assume that a cylinder partially filled with air is fitted with a piston. The air has a given temperature, and a pressure corresponding to that of the atmosphere plus the weight of the piston which it supports. Should heat now be applied and the temperature of the air increased, its volume will also be increased and the piston will move, the pressure, of course, remaining the same as before. If now the piston is replaced by a rigid air-tight diaphragm, and heat is applied, the volume cannot increase, but an increase in pressure will result. Furthermore, if the piston should be moved so as to increase the pressure and reduce the volume of the air, there would be be an increase in temperature; hence, the pressure, volume, and temperature are intimately connected, and must all be considered in the design of a compressor. (See also Indicator Diagrams.)

Work Hardening. This is the name given to the increase in hardness and strength that occurs when a metal is plastically deformed below its recrystallization temperature.

Working Gage. "Working gages" are those which are used in testing the work for size during the actual manufacture of the part. This type of gage has a greater amount allowed for wear than any other type, and hence the actual tolerance on the work between the maximum and minimum gage is smaller, by the amount allowed for wear on the gage, than the actual amount specified on the drawing. See Gage Classification.

Working Load. See Stress Definitions.

Working Points. The working or register points are those surfaces that are employed for locating parts in the jigs and fixtures during the process of manufacture. Sometimes important functional surfaces are used for this purpose. In other cases, for parts of irregular form, special lugs are provided and are removed after the machining operations are complete. As few locating points as possible should be established because this practice simplifies the design of the gages and other equipment.

Worm-Gear Applications. Worm gearing is employed for transmitting motion between two shafts which are at right angles to each other but which are not in the same plane. Strictly speaking, worm gearing is, therefore, a modified form of spiral or helical gearing, in which one gear takes the form of a screw or worm provided with threads, and the other of a gear with teeth inclined at the same angle as the threads in the worm.

Worm gearing may be employed (1) as an efficient, steady transmitter of power; (2) when a large reduction in velocity is desired; (3) when considerable increase in "mechanical advantage" is required, or, in other words, when a given applied force must overcome a comparatively high resistance to motion. Many worm-gears of the higher ratios are self-locking but very inefficient. Such gears, however, usually are applied to intermittent service, or where the waste of power due to the decreased efficiency of self-locking worm gearing is of little or no importance. The best material for worm gearing is hard phosphor-bronze for the worm-wheel and hardened steel for the worm. The next best materials are cast iron for the worm-wheel and hardened steel or cast iron for the worm. Steel or steel castings for both the worm-wheel and worm are only allowable for slow speeds. The teeth in the worm-wheel and the thread on the worm should always be cut, whenever the gearing is to be used steadily or at a reasonably high speed.

Worm-Gear Bronze. See Gear Castings, Bronze.

Worm-Gear Cutting. The machines used for cutting worm-gears include ordinary milling machines, gear-hobbing machines of the type adapted to cutting either spur, spiral, or worm gearing, and special machines designed expressly for cutting worm-gears. The general methods employed are (1) cutting by using a straight hob and a radial feeding movement between hob and gear blank; (2) cutting by feeding a fly cutter tangentially with relation to the worm gear blank; and (3) cutting by feeding a tapering hob tangentially. The fly-cutter method is slow as compared with hobbing but it has two decided advantages: First, a very simple and inexpensive cutter may be used instead of an

expensive hob. This is of great importance when the number of worm-gears is not large enough to warrant making a hob. Second, with the fly-cutter method, it is possible to produce worm-gears having more accurate teeth than are obtainable by the use of a straight hob. Taper hobs are especially adapted for cutting worm-gears that are to mesh with worms having large helix angles; they are also preferable for worm-gears having large face widths in proportion to the worm diameter. Worm-gear teeth are generated more accurately with a taper hob than with a straight hob that is given a radial feeding movement.

Worm Gearing, Hindley. See Hindley Worm Gearing.

Worm-Gear Power-Transmitting Capacity. In determining the allowable load for worm gearing, the danger of overheating and of abrasion is usually of greater importance than the strength, because if the gearing is so proportioned as to prevent abrasion and overheating, the strength will ordinarily be greater than is required merely to withstand the stresses due to the load. Overheating is the cause of most worm-gear failures. It indicates that the frictional loss is so great that the heat is generated faster than it can be dissipated; consequently the action of the lubricant becomes less effective as the temperature rises, which, in turn, causes a further increase in frictional resistance. Finally, the oil film between the surfaces and contact is no longer maintained and abrasion begins. It is evident that there is less danger of overheating and abrasion with lower velocities and intermittent service, and also when a lubricant of good quality is used.

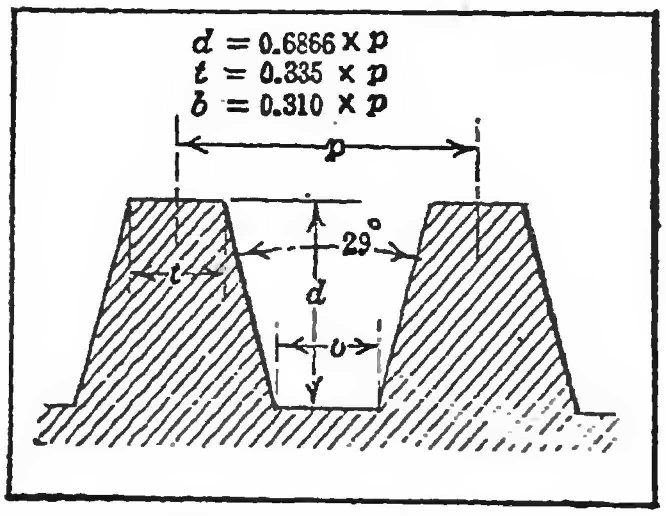
In designing worm drives, the worm diameter should be as small as possible to reduce the velocity. If the worm diameter is unnecessarily large, the gearing may become hot and start to cut. Another important point is to use a multiple-threaded worm in preference to a single-threaded worm, whenever conditions permit, to increase efficiency. For determining the power that worm gearing will transmit without danger of excessive heating or abrasion, the Lewis formula for spur gears may be used, the calculations being based on the velocity of the worm-gear; that is, insert in the formula for spur gears the velocity of the worm-gear in feet per minute, its diametral pitch, and face width as measured along the pitch circle of the worm.

Worm Thread Cutting. Worm threads are cut either by using some form of thread-cutting lathe and a single-point tool, by using a thread milling machine and a disk type of cutter, or by using a gear-hobbing machine. Single-thread worms usually have an included angle of 29 degrees. Many worm gears used at the present time, especially for power transmission, have thread angles larger than 29 degrees because multiple-thread

worms are used to obtain higher efficiency, and larger thread angles are necessary in order to avoid excessive under-cutting of the worm-wheel teeth. According to the recommended practice of the American Gear Manufacturers' Association, worms having triple and quadruple threads should have a thread angle of 40 degrees, and some manufacturers of worm gearing, especially when the helix or lead angle of the thread is quite large, use a thread angle of 60 degrees.

If the helix or lead angle of the worm thread exceeds 15 or 20 degrees, it is common practice to reduce the depth of the thread by using the normal instead of the axial pitch of the worm in the formulas. Thus, if P_n equals normal pitch, the total depth equals $P_n \times 0.6866$ instead of $P \times 0.6866$. This normal pitch P_n equals $P \times$ cosine of the helix angle. According to the recommended practice of the American Gear Manufacturers' Association, the whole depth for single- and double-thread worms equals $P \times 0.686$, and for triple- and quadruple-thread worms equals $P \times 0.623$.

Worm Threads. The included angles of worm threads may range from 29 degrees up to 60 degrees. While 29 degrees (see illustration) is a common angle for single-threaded worms, the multiple-threaded type used for efficient power transmission must have comparatively large helix angles and, consequently, increased thread angles to avoid excessive under-cutting in hobbing the worm-wheel teeth. The American Gear Manufacturers' Association recommends a 40-degree included thread angle for triple- and quadruple-thread worms, but many speed reducers and other transmissions have thread angles of 60 degrees. The angle of 29 degrees is the same as that of the Acme thread, but the worm thread depth is greater and the widths of the flats at the top and bottom are less. If the lead angle or angle between the worm thread helix at the pitch cylinder and a plane perpendicular to the worm axis, is comparatively large, difficulties may be encountered if a 29-degree worm thread is employed. If the lead angle is larger than about 20 degrees, an increase in the included thread angle is desirable. As the efficiency of worm gearing reaches a maximum when the lead angle is about 45 degrees, this explains why 60-degree thread angles have been applied in many transmissions. The formulas for the thread parts of a 29-degree worm thread are as follows:



29-degree Worm Thread

$$p = \text{pitch} = \frac{1}{\text{No. of threads per inch}};$$

$$d = \text{depth of thread} = 0.6866\ p = \frac{0.6866}{\text{No. of threads per inch}};$$

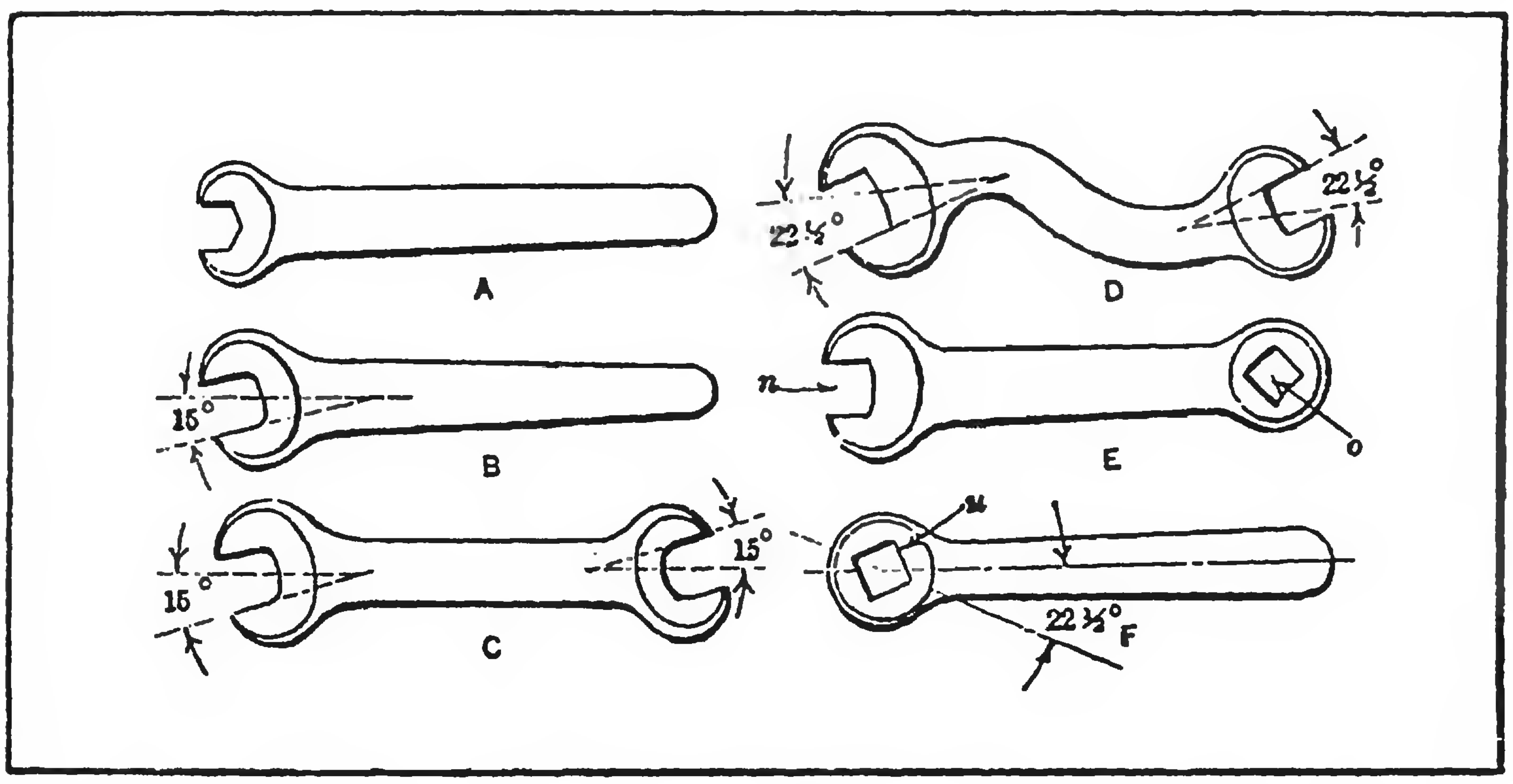
$$t = \text{width at top of thread} = 0.335\ p;$$

$$b = \text{width at bottom of thread} = 0.310\ p.$$

Worthite. A high-nickel, high-chromium molybdenum allov steel suitable for all purposes where chromium-iron alloys or nickel-chromium stainless steels are applicable, and, in addition for purposes where its ability to resist sulphuric acid is of especial value. Tensile strength, 67,000 to 75,000 pounds per square inch; yield point, 30,000 to 35,000 pounds per square inch; elongation in 2 inches, 35 to 45 per cent; reduction in area, 35 to 45 per cent; Brinell hardness, 125 to 150. Resistant to sulphuric acid and to weak muriatic acid, but should not be used for hot sulphuric acid above 50 per cent concentration, nor for halogen acids, except very weak solutions.

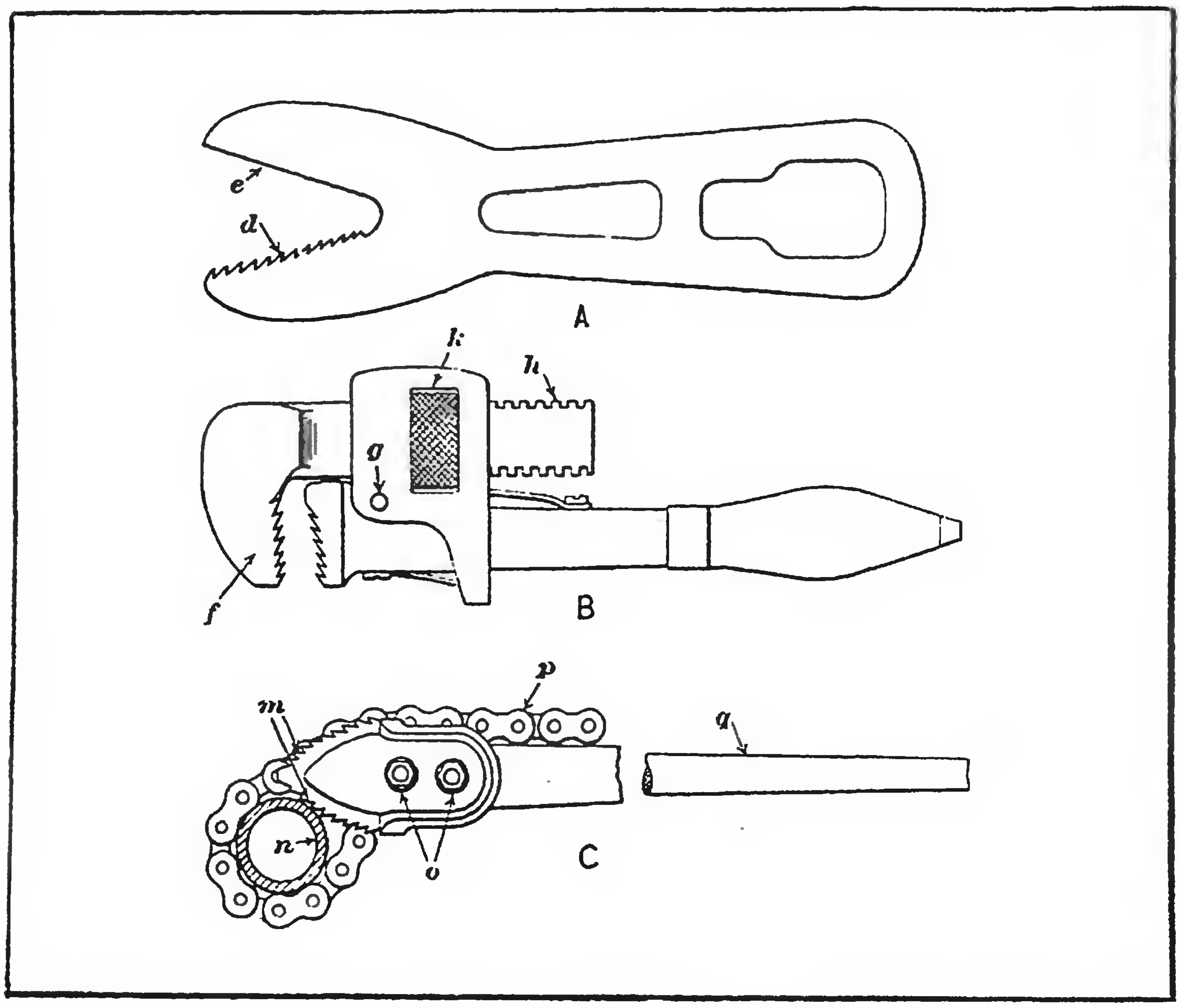
Wortle Steel. The special class of tungsten steels known as wortle or cold-drawing die steels, possess unusual resistance to wear and are used in connection with draw-benches for drawing wire and rod. The so-called soft wortle steels usually contain from 1.5 to 3 per cent tungsten; about 2 per cent carbon; and from 0.50 to 0.80 per cent manganese. Such steels are adapted for drawing soft wire, "rounds" and shapes. A hard wortle steel for fine wire drawing contains 11 to 12 per cent tungsten; 1.85 to 1.95 per cent carbon; about 2 per cent manganese, and the same amount of chromium.

Wrenches. A group of wrenches commonly used in general



Non-adjustable Wrenches

mechanical work is shown by the engraving. The *straight single-end wrench* at *A* is designed for use on either hexagon or square nuts and bolts, on plain work where there are no interferences. This type of wrench is also made double, with a different size of opening at each end. The *single-end* 15-*degree angle wrench,* shown at *B*, is a very common type of wrench, the offset of which is made in order to permit its use in more confined situations, where the handle might strike if it were made straight. The *double-end* 15-*degree angle wrench C* is of the same general type as *B*, the ends being offset and with different sizes of openings. The *double-end* 22½-*degree angle wrench D* is particularly useful in loom repairing and for textile workers. It is intended especially for square-head nuts and bolts on account of the greater swing of wrench needed in setting up. The *double-head toolpost wrench E* is made with one end *o* broached square, so that it is not likely to slip off the post when in use. The other end *n* is usually made to take some standard size of nut used on the machine. The *square-box* 22½-*degree angle toolpost wrench F* is also broached and is designed primarily for a lathe toolpost. The



Alligator and Pipe Wrenches

angle of the broached hole *u*, in relation to the handle, is such as to give greater latitude when the operator's hand is likely to

come in contact with the work, or portions of the machine. The offsets commonly used for non-adjustable wrenches are 15 degrees for a hexagon and 22½ degrees for a square-head bolt or nut, these angularities being, in each case, one-quarter of the angle of the arc subtended by one side of the nut. When nuts are located in such a way that there is not sufficient room to swing a straight wrench through the necessary angle, the offset type can be used to advantage. See Socket Wrenches; Spanner Wrenches.

Wrenches for Cylindrical Work. The *alligator wrench* at *A* indicates clearly the origin of its name. One of the jaws *d* is provided with a set of teeth, while the other, *e*, is smooth. When in use, the teeth "bite" into the pipe or other cylindrical work, and a wedging action takes place as the pipe works farther up into the jaws, so that it becomes tighter as pressure is applied. The *Stillson* type of wrench, *B*, is commonly used for pipe work of all kinds. The jaw *f* is L-shaped, flattened on the sides, and has a thread of coarse pitch at *h*. The jaw is mounted in a holder pivoted at *g* to the solid portion of the wrench, the adjustment being obtained through the knurled nut *k*. When pressure is applied, the pivoted portion in connection with the fixed jaw tends to grip the work more and more tightly, according to the amount of force used in the application. The *chain-type of wrench, C*, is commonly used on work requiring considerable leverage, such as heavy steam fitting and street pipe work. The handle *q* is often made in lengths of from 2 to 6 feet. There are two jaws *m*, one of which is fastened to each side of the bar by the nuts and bolts at *o*, these jaws being provided with teeth which "bite" into any cylindrical object on which they are used, as shown at *n* in the illustration. The chain portion *p* may be drawn around the pipe to an approximation of the correct diameter, after which provision is made between the jaws for tightening the chain. This is done either by means of protruding lugs, or by an extension of the rivet ends through the chain blocks in such a way that they will drop into slots in the jaws.

Wringing Fit. This is a fit between two parts, one cylindrical and the other with a cylindrical bore, of such a character that one part cannot be pushed easily into the other, but can be made to enter by a twisting motion, the parts being turned or twisted as they are forced or "wrung" together by hand.

Wrought Iron. Wrought iron is a slag-bearing malleable iron which contains comparatively little carbon (.08 per cent or less). It is more easily forged than steel and can be welded readily; it cannot be hardened or heat-treated the same as steel, but can be casehardened by the use of cyanide of potassium. It has a high

electrical conductivity and magnetizes easily. Wrought iron should never be used for bearing surfaces, as its slag content causes heating and wear, but it is suitable for parts such as chain links, rods, angles, braces, levers, etc., and for use when subjected to high temperatures.

Grades of Wrought Iron: Wrought iron is graded in many ways, there being no standard system. It is sometimes divided simply into two classes—*charcoal iron*, which is made from charcoal pig and is usually refined and double refined, and *common iron*, which is made from coke pig. According to another system, it is graded in three classes as *charcoal iron; puddle iron*, which is divided into Classes A, B, and C, or into staybolt iron and merchant iron; and *busheled scrap iron*, which is made from iron scrap which frequently contains pieces of steel. According to still another classification, it is graded as *Norway* or, more correctly, *Swedish iron*, which is very fibrous and used for the best class of work; *double-refined* or *best-refined iron*, which is the best domestic iron, and is used for forging, welding, and machine work; *refined iron*, which is a good grade of wrought iron; and *common iron*, which is made either from pig iron or from scrap, and which does not weld as readily as the other grades.

Wrought iron has, to a large extent, been superseded by mild steel. Nevertheless, its resistance to fatigue and the ease with which it can be welded render it valuable for many purposes. Although it is frequently referred to as "Norway" iron, probably the best wrought iron made comes from Sweden. This iron is unusually free from sulphur and phosphorous—ingredients which have an injurious effect upon the metal.

Strength of Wrought Iron: Wrought iron is ductile and malleable. Its strength and physical properties depend upon various conditions, but the ultimate strength in tension is about 48,000 to 50,000 pounds per square inch. If wrought iron is assumed to have a strength of 100 per cent at 70 degrees F., its strength at 400 degrees F. is about 112 per cent and at 570 degrees F., 116 per cent, after which there is a falling off, so that the strength at 750 degrees F. is 96 per cent, and at 1100 degrees F., 42 per cent.

Refined and Double-refined Wrought Iron: Refined wrought iron is made by melting pig iron and puddling it in a puddle furnace in the same way as common iron. The bars, however, are subjected to a second heating and re-rolling, thus producing what is known as "refined" iron. *Double-refined iron* is also made from pig iron, and passes through the same process in the puddling furnace, and is rolled through the puddle rolls, cut up, heated, and re-rolled the same as refined iron, but the bars thus obtained are again cut up, made into box piles, reheated, and again run

through the rolls. The double rolling of the metal makes it very fibrous. Double-refined wrought iron is a very good material having an ultimate tensile strength of about 50,000 pounds per square inch with an elongation of 28 per cent. It is used extensively in the construction of passenger and freight cars, because of its ductility and its quality of being able to withstand shocks and constant vibration better than steel.

Wrought Pipe Defined. The terms "wrought pipe" and "wrought-iron pipe," at one time were practically synonymous, for originally all pipe was made of wrought iron, but the use of steel pipe has increased so rapidly that now at least 90 per cent of the wrought pipe made in this country is of that material. "Wrought pipe" is a term that is applied to both steel and iron pipe. The term "wrought-iron pipe" means that the pipe is made of wrought iron, which is the product of the puddling furnace; while "steel pipe" is applied, of course, only to pipe made of steel.

Wuest Herringbone Gears. See under Herringbone Gears.

X

X-rays. X-rays, also known from their discoverer as *Rontgen rays*, are generated when the cathode rays of a vacuum tube impinge upon any solid substance. All substances, many of which are opaque to ordinary light, transmit X-rays to some degree. A somewhat interesting relationship exists between the transparency of any substance and its specific gravity; the transparency to X-rays is approximately inversely proportional to the specific gravity of the substance. X-rays are of the same general character as light waves, but so short that they readily penetrate all sorts of materials usually opaque to visible light. They are produced commercially by a very high voltage discharge in a special type of vacuum tube, and their ability to penetrate materials increases with the voltage, but decreases as the atomic weight of the materials increases. Thus, X-rays produced at 100,000 volts may penetrate satisfactorily an inch of steel, several inches of aluminum or a foot or more of wood, whereas more than 200,000 volts would be required to produce X-rays to penetrate three inches of steel. Specially designed 220 kilovolt X-ray equipment mounted on a portable carriage is being used for this purpose in industry.

The usual way of recording X-rays is by the "shadow picture," or radiograph, formed on a photographic film. As with ordinary photographs, darker regions on the negative or lighter regions on the print mean that more light has passed through the object at that place—that is, the object is more transparent there. In some instances a fluoroscopic screen may be used for direct observation of the image, much as a "moving picture" would be viewed.

Serious waste in the machine shop often occurs because of internal defects discovered in the work after considerable machining has been done. While these conditions are, perhaps, more prevalent in castings, they also occur in forgings and in bar or plate stock. Where it is a question of machining large and important castings, X-ray inspections may be of particular importance. Detailed pictures of all sorts of cast articles can be secured with comparative ease and speed, so long as the greatest thickness does not exceed 3½ inches of steel or its equivalent.

Equipment which can be used in making X-ray pictures of castings, etc., consists of a high-voltage power plant capable of

producing 280,000 volts, an X-ray tube mounted in a lead-covered steel drum to prevent the escape of X-rays except through predetermined openings, and an exposure cabinet provided with movable lead screens to surround the object under examination. Arrangements also have been effected whereby small metal parts may pass in front of a fluoroscopic screen for continuous inspection.

Xylene. Name applied to any of three isomeric hydrocarbons, $C_6H_4(CH_3)_2$, of the benzene series, found in coal and wood tar and certain kinds of petroleum, and also prepared artificially. They are dimethyl derivatives of benzene and are called specifically orthoxylene, metaxylene or isoxylene, and paraxylene. All are ordinarily coloress oily liquids, and each is the parent substance of a distinct series of compounds.

Y

Yard. One yard equals 3 feet or 36 inches. Since 1893 the United States yard and its subdivisions have been derived from the international meter. The basic relation officially recognized is that contained in the law of July 28, 1866, and set forth in the Mendenhall order of April 5, 1893; namely,

$$\frac{1 \text{ yard}}{1 \text{ meter}} = \frac{3{,}600}{3{,}937}$$

Y-Connections. In a three-phase, alternating-current system, the generators and motors are designed with three windings or phases, connected either in mesh or with delta connection, in which case the diagram of the three windings forms a Greek letter delta ($\triangle$), or in star or Y-connection, when the diagram of the three windings forms a Y.

Yellow Metal. This is a brass containing about 40 per cent of zinc and 60 per cent of copper. See Brass Alloys for Castings.

Y-Fitting or Wye. A fitting either cast or wrought that has one side outlet at any angle other than 90 degrees. The angle is usually 45 degrees, unless another angle is specified. The fitting is usually indicated by the letter Y.

Yield-Point. When testing a bar of metal in a testing machine, a point will be arrived at where there will be an extension of the bar without an increase of the load. This point is called the *yield point*. Practically, it may be considered as the point at which a certain load per square inch will cause a distinctly visible increase in the distance between the gage points on the test-piece; or it may be considered to be the point at which, when the load is increased at a moderately fast rate, there is a distinct drop of the testing machine lever, or, in hydraulic testing machines, of the gage finger. A steel test-piece at the yield-point shows rapidly a large increase of extension. The yield-point should not be confused with the elastic limit, which is the point at which extensions in a material under stress cease to be proportional to the loads.

Yield Strength. Yield strength is usually defined as that stress at which metal exhibits a specified limited deviation from the proportionality of stress to strain. Often, it is expressed

as the stress at which a permanent set of 0.2 per cent (or 0.002 inch per inch) occurs.

Yoloy. A nickel-copper alloy steel produced in sheets, strips, bars, plates, shapes, wire, and seamless pipe. Has exceptional resistance to corrosion, high tensile strength, high ductility, workability, and weldability. Low-strength Yoloy has a tensile strength of 74,000 pounds per square inch; high-strength Yoloy, 92,000 pounds per square inch. For use where resistance to corrosion is essential, where abrasion must be withstood, and where long life is desired for the same weight of material, or equal life with lighter weight.

Young's Modulus. The modulus of elasticity of a material —that is, the quotient obtained by dividing the stress per square inch by the elongation in one inch caused by this stress—is often referred to as *Young's modulus,* from the name of the first investigator who pointed out this relationship.

Z

Zee Section. A standard structural shape consisting of a web and flanges extending at right angles to the web but in opposite directions. See Structural Shapes.

Zerener Electric Welding Process. In the Zerener electric welding process (also known as the "electric blow-pipe" method), an electric arc is drawn between two carbon electrodes. This arc is then caused to impinge upon the metal surfaces to be welded by means of an electro-magnet. The arc is pointed to concentrate the heat, and the metal is fused around its point of contact with the arc.

Zero, Absolute. See Absolute Temperature.

Zerol Bevel Gears. Gears of this type have curved teeth but the spiral angle is zero, which explains the derivation of the name. These gears may be cut and ground on the same Gleason machines that are used for spiral bevel and hypoid gears. Zerol bevel gears combine the low axial thrust of straight bevel gears, with the local tooth contact of spiral bevel gears. They can be used to replace straight bevel gears without mounting changes, when the thrust limitations prevent the use of spiral bevel gears.

Zilloy. A rolled zinc which is stronger, and has greater heat resistance than the commercial grades of rolled zinc, but possesses the same corrosion-resistant characteristics. Fabricated and finished by similar methods to those used for commercial grades. Suitable for fabrication into screen frames, screen guides, splines, weather-strips, corner beadings and moldings, as well as for zinc stampings of greater strength than obtainable from commercial grades of rolled zinc.

Zinc. Zinc is a metallic chemical element. Its chemical symbol is Zn; atomic weight, 65.37; melting point, 786 degrees F. (419 degrees C.); boiling point, at atmospheric pressure, 1904 degrees F. (1040 degrees C.). The specific gravity of cast zinc is from 6.86 to 6.91; specific gravity of rolled zinc, from 7.15 to 7.19; coefficient of linear expansion per unit of length per degree F., 0.000014; specific heat, 0.095; latent heat of fusion, 50.6 B.T.U. per pound; heat transmitted, per second, through metal 1 inch thick, per square inch of surface, for a temperature difference of 1 degree F., 0.0017 B.T.U.; heat conductivity compared with silver (silver = 100), 36; electric conductivity (silver = 100), 29.6; ultimate tensile strength of cast zinc, about 5000 pounds

per square inch (but may vary from 4000 to 14,000 pounds per square inch); ultimate strength in compression, about 20,000 pounds per square inch; modulus of elasticity, 13,000,000. Commercial zinc is generally known as *spelter*.

Zinc Ores: Zinc does not occur free in nature, although it is very common in various combinations. The four important ores are zinc oxide, zinc sulphide, or blende, zinc silicate, and zinc sulphate. The greater part of zinc found in nature is in the form of zinc sulphide, but, as this is infusible, it must be oxidized, when zinc oxide, zinc sulphide, and sulphur dioxide are formed. By heating zinc silicate to a high temperature, it is reduced by carbon, and metallic zinc, carbon monoxide, and silica slag are formed. All zinc ores, except the oxides, are first converted into zinc oxide, which is then distilled with carbon, and the distillate of metallic zinc is condensed. This metallic zinc is refined in a furnace.

Zinc is used in many brass compositions and in zinc-base die-casting alloys. Another important use is for protecting steel and iron against corrosion by a coating of zinc.

Zinc-Aluminum Alloys. See Aluminum Alloys, Cast.

Zinc Castings. Pure zinc castings are used for certain special purposes. For example, the dies or blocks on which hats are made are usually cast from zinc. The patterns for pure zinc castings are usually made from plaster-of-paris, and the molding is similar to that of other metals. Another use for cast zinc is for making monuments and statues, the metal then being marketed under the name of "white bronze." For many purposes of inside decoration, a metal casting that can be easily bronzed or otherwise finished is desirable. Zinc, when alloyed with some copper, is frequently used, although, as a general rule, brass or bronze castings are preferable. Brass and bronze, however, must be cast at a temperature of from 1700 to 1900 degrees F., according to the composition of the alloy, whereas zinc, alloyed with a small amount of copper, can be cast at a temperature of from about 800 to 900 degrees F., which is an important consideration, especially when plaster molds are used.

Zinc Cement. Zinc cement is a cement composed of zinc oxide which is made into a paste by means of a solution of zinc chloride. The peculiar quality of zinc cement is that it hardens quickly, and it may, therefore, be used for various purposes where this quality is of value. A cheaper form of zinc cement may be made from commercial zinc-white, mixed with an equal weight of fine sand, and made into a paste by means of a solution of zinc chloride. This cement is frequently used for filling cracks in metals, and for cementing glass, porcelain, etc.

Zinc Chromate. Zinc chromate is a yellow pigment made from zinc salts and potassium dichromate. It is fairly soluble in water and generally contains other chromates and zinc oxide, with some impurities. It has a specific gravity of 3.5, and grinds to a paste in 25 per cent of oil. Considerable drier is required as it is a slow drying material, but it has proved to be one of the most inhibitive of all pigments in use and is valuable in even small amounts in protective paints. Its rather high price is its only disadvantage.

Zinc-Dust. Zinc-dust, also known as *zinc powder*, is metallic zinc in the form of a fine powder. It may be obtained in two ways: 1. By grinding zinc, heated to a temperature of from 400 to 500 degrees F., in an iron mortar. 2. By rapid cooling of zinc vapor in the reduction of the metal from its ores. In this case, the zinc-dust is more or less mixed with zinc oxide. Zinc-dust is used as a deoxidizing agent in the textile industries, and also in making protective paints for iron work.

Zinc Gage. This gage applies to sheet zinc only. For zinc wire the American or Brown & Sharpe wire gage is employed. Tables of these gages are in MACHINERY'S HANDBOOK.

Zinc Iron. Zinc iron is an alloy of iron and zinc, obtained by dissolving the iron in molten zinc at a high temperature. This alloy is used for introducing iron into copper-zinc and copper-tin alloys.

Zinsol. A solution or compound which, when applied to metal surfaces, forms a surface that is chemically inert to moisture, the atmosphere, and organic finishes, so as to form a stable foundation for any desired finish. Used for treating the surfaces of zinc, zinc-coated, or galvanized products before finishing them with lacquer, enamel, paint, or varnish. The zinc or zinc-coated products are dipped into or wiped with the solution.

Zircofrax. Tubes, combustion "boats," and covers, made from zirconium silicate, for use in steel and alloy manufacturing plant laboratories. The "boats" and covers will withstand temperatures up to 2820 degrees F., and the gas-tight tubes over 2900 degrees F. Applicable for laboratory equipment at temperatures well above those required in the analysis of steels and alloys with high melting temperature.

Zisium. Zisium is a trade name for an alloy of aluminum, zinc, tin, and copper, aluminum being the chief constituent. Traces of antimony and bismuth are also present. The alloy is used in the making of scientific instruments. *Ziskon* is another trade name used for an alloy of aluminum and zinc, containing about 75 per cent of aluminum and 25 per cent of zinc. The alloy is also used in the making of scientific instruments.

Z-Nickel. A nickel alloy containing 98 per cent nickel, which has the corrosion-resistant properties of nickel combined with the mechanical properties of high-strength alloy steel. It has been produced with a tensile strength as high as 250,000 pounds per square inch, and a hardness as high as 46 Rockwell C. Commercial cold-rolled strip, unhardened, varies in tensile strength from 90,000 to 155,000 pounds per square inch, and heat-treated strip from 120,000 to 220,000 pounds per square inch.